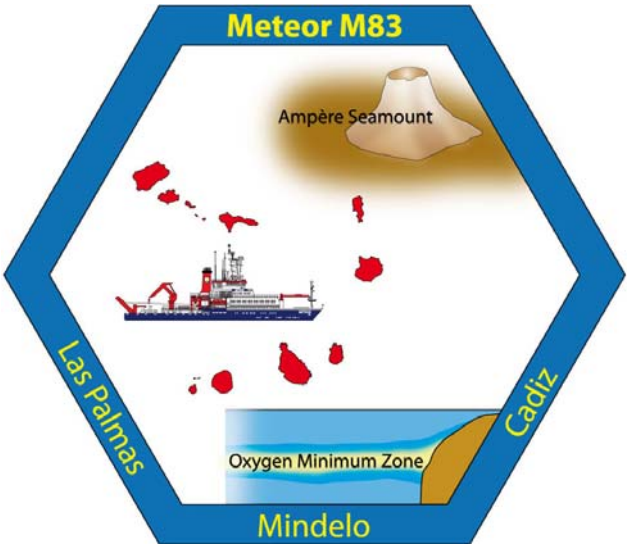
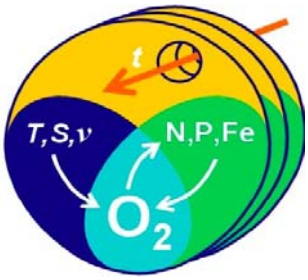
METEOR-Berichte

Tracer survey in the Cape Verde region

Cruise No. M83/1

October 14 – November 13, 2010
Las Palmas (Spain) – Mindelo (Cape Verde Islands)





SFB 754

M. Visbeck

Editorial Assistance:

DFG-Senatskommission für Ozeanographie
MARUM – Zentrum für Marine Umweltwissenschaften der Universität Bremen

2013

The METEOR-Berichte are published at irregular intervals. They are working papers for people who are occupied with the respective expedition and are intended as reports for the funding institutions. The opinions expressed in the METEOR-Berichte are only those of the authors.

The METEOR expeditions are funded by the *Deutsche Forschungsgemeinschaft (DFG)* and the *Bundesministerium für Bildung und Forschung (BMBF)*.

Editor:
DFG-Senatskommission für Ozeanographie
c/o MARUM – Zentrum für Marine Umweltwissenschaften
Universität Bremen
Leobener Strasse
28359 Bremen

Author:
Prof. Dr. Martin Visbeck
IFM-GEOMAR
Leibniz-Institut für Meereswissenschaften
an der Universität Kiel
Düsternbrooker Weg 20

Tel. +49 – 431 – 600 4100
Fax +49 – 431 – 600 4102
email mvisbeck@geomar.de
www.geomar.de

Citation: Martin Visbeck (2013) Tracer survey in the Cape Verde region – Cruise No. M83/1 – October 14 – November 13, 2010 - Las Palmas (Spain) – Mindelo (Cape Verde Islands). METEOR-Berichte, M83/1, 46 pp., DFG-Senatskommission für Ozeanographie, DOI:10.2312/cr_m83_1

ISSN 2195-8475

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1 Summary

During leg M83/1 a combined chemical, physical oceanographic and biological research cruise was made in the northeastern tropical Atlantic in order to obtain a better understanding of the dynamics and variability of tropical oxygen minimum zones within the framework of the SFB 754 (Climate – Biogeochemical interactions in the tropical Oceans). The main goal of the leg M83/1 was to resurvey the purposeful tracer release patch about 2.5 years after its injection in April 2008. Further objectives included water mass variability and oxygen/nutrient distributions in the survey region, analysis of transient tracer data to better understand ventilation and abundance of anthropogenic carbon in the area. Moreover, data obtained during the cruise helps delineate water mass transport pathways within the shallow subtropical cell with a particular focus on the exchanges between the Guinea upwelling region and the tropical ocean interior. Biogeochemical sampling was carried out for nitrous oxide and DNA/RNA as well as phytoplankton pigments, biogenic silicate, dissolved/particulate organic matter and zooplankton investigations. Special chemical investigations were carried out to investigate irradiance effects on trace metal redox cycles and trace metal specification.

Zusammenfassung

Im Rahmen des SFB-754 (Klima-biogeochemische Wechselwirkungen im tropischen Ozean) wurde auf dem Abschnitt M83/1 eine kombinierte chemische, physikalische und biologische Forschungsfahrt im nordöstlichen tropischen Atlantik durchgeführt, um ein besseres Verständnis der Dynamik und Variabilität der tropischen Sauerstoffminimum Zonen zu erhalten. Das Hauptziel auf dem Abschnitt M83/1 war die erneute Vermessung der Ausbreitung eines Tracers ungefähr 2,5 Jahre nach der Ausbringung im April 2008. Ein weiteres Ziel beinhaltete die Untersuchung von Wassermassen Variabilität und Sauerstoff/Nährstoff-Verteilungen in der Untersuchungsregion. Tracerdaten wurden analysiert, um die Ventilation und den Gehalt anthropogenen Kohlenstoffs in dem Gebiet besser zu verstehen. Die Reise lieferte weiterhin Aufschlüsse über die Pfade der Wassermassenausbreitung in der flachen subtropischen Zelle. Ein Schwerpunkt lag auf dem Austausch zwischen der Guinea Auftriebsregion und dem inneren tropischen Ozean. Biogeochemische Probenahme wurde zu Untersuchungen von für Stickoxyden-, und DNA/RNA sowie für Phytoplankton Pigmente, biogenes Silikat, gelöste/partikuläre organische Substanzen und Zooplankton durchgeführt. Spezielle chemische Untersuchungen wurden zu Bestrahlungseinflüssen von Redoxzyklen auf Spurenmetall und der Spezifikation von Spurenmetall ausgeführt.

2 Participants

Name	Discipline	Institution
Visbeck, Martin, Prof. Dr.	Chief scientist	IFM-GEOMAR
Banyte, Donata	CTD-Watch/Salinometer	IFM-GEOMAR
Baustian, Tina	Nitrogen fixation	IFM-GEOMAR
Bieligk, Henner	Tracer	IFM-GEOMAR
Bogner, Boie	Tracer	IFM-GEOMAR
Bracamonte, Seraina	Nitrogen loss	IFM-GEOMAR
Franz, Jasmin	Biochemistry	IFM-GEOMAR
Gleixner, Stephanie	CTD/ADCP	IFM-GEOMAR
Haase, Sabine	Microstructure	IFM-GEOMAR
Hauss, Helena	Mesocosms	IFM-GEOMAR
Heller, Maija, Dr.	Redox Species	IFM-GEOMAR
Krahmann, Gerd, Dr.	ADCP-processing/Glider	IFM-GEOMAR
Link, Rudolf	CTD/ADCP	IFM-GEOMAR
Lohmann, Martina	Technician	IFM-GEOMAR
Löscher, Carolin	Nitrogen fixation/loss	IFM-GEOMAR
Lüttschwager, Gunther	CTD/ADCP	IFM-GEOMAR
Manke, Anne	Tracer	IFM-GEOMAR
Nachtigall, Kerstin	Nutrients	IFM-GEOMAR
Nam Koong, Hansup	Tracer	IFM-GEOMAR
Schaffer, Janin	CTD/ADCP	IFM-GEOMAR
Stange, Karen	Oxygen	IFM-GEOMAR
Stöven, Tim	Tracer	IFM-GEOMAR
Stramma, Lothar; Dr.	CTD-Mapping/Salinometer	IFM-GEOMAR
Tanhua, Toste, Dr.	Tracer	IFM-GEOMAR
Wuttig, Kathrin	Redox Species	IFM-GEOMAR
Rake, Andreas	Weather technician	DWD
DaSilva, Pericles	Nitrogen fixation	INDP
Diallo, Samba T.	Observer Guinea	CNSHB
Ly, Youssouph O.	Observer Senegal	Observer

IFM-GEOMAR
Leibniz-Institut für Meereswissenschaften
an der Universität Kiel
Wischhofstr. 1-3
24148 Kiel / Germany
e-mail: info@ifm-geomar.de
www.ifm-geomar.de

CNSHB
Centre National des Sciences Halieutiques se Boussoura
814 Rue MA 500,
Corniche Sud
Madina, Boussoura Port
Conakry/Guinea

INDP
Instituto de Desenvolvimento das Pescas
Cova de Inglesa, P.B. 132
Mindelo, S. Vicente / Cape Verde

DWD
Deutscher Wetterdienst
Geschäftsfeld Seeschifffahrt
Bernhard-Nocht-Straße 76
20359 Hamburg / Germany
e-mail:seeschifffahrt@dwd.de
www.dwd.de

3 Research Program

The primary goal for this cruise was to:

• Document the lateral and vertical distribution of a deliberately released tracer 30 months after its deployment.

From this distribution we examined regional advection as well as lateral and vertical mixing rates. The observed distribution was compared with high-resolution models of the tracer in the region. The resulting information will be applied to measurements of regional oxygen gradients in order to better understand the supply of oxygen to the OMZ. The data from this and the previous two survey cruises have been submitted for publication.

Additional objectives of the cruise include:

- Compilation of a detailed and dense map of the oxygen distribution in the region. The data are used to estimate the oxygen inventory and its changes over time within this OMZ.
- Collect transient tracer data to study ventilation in the thermocline and to determine the anthropogenic carbon content in the water column.

- Collect of data on oxygen sensitive trace metal distributions within this OMZ.
- Examine changes in redox sensitive species (Mn^{2+}, IO_3^-) within the tracer patch.
- To investigate and conceptualize re-sponses of the pelagic community on OMZ-induced changes in the nutrient stoichiometry, in terms of phyto-plankton biomass, its taxonomical composition and the stoichiometry of zooplankton.

The cruise was very successful and all measurements were carried out as planned with only slight modifications. A list of the stations (Figure 3.1) shows the large scale sampling of the tracer patch and associated measurments.

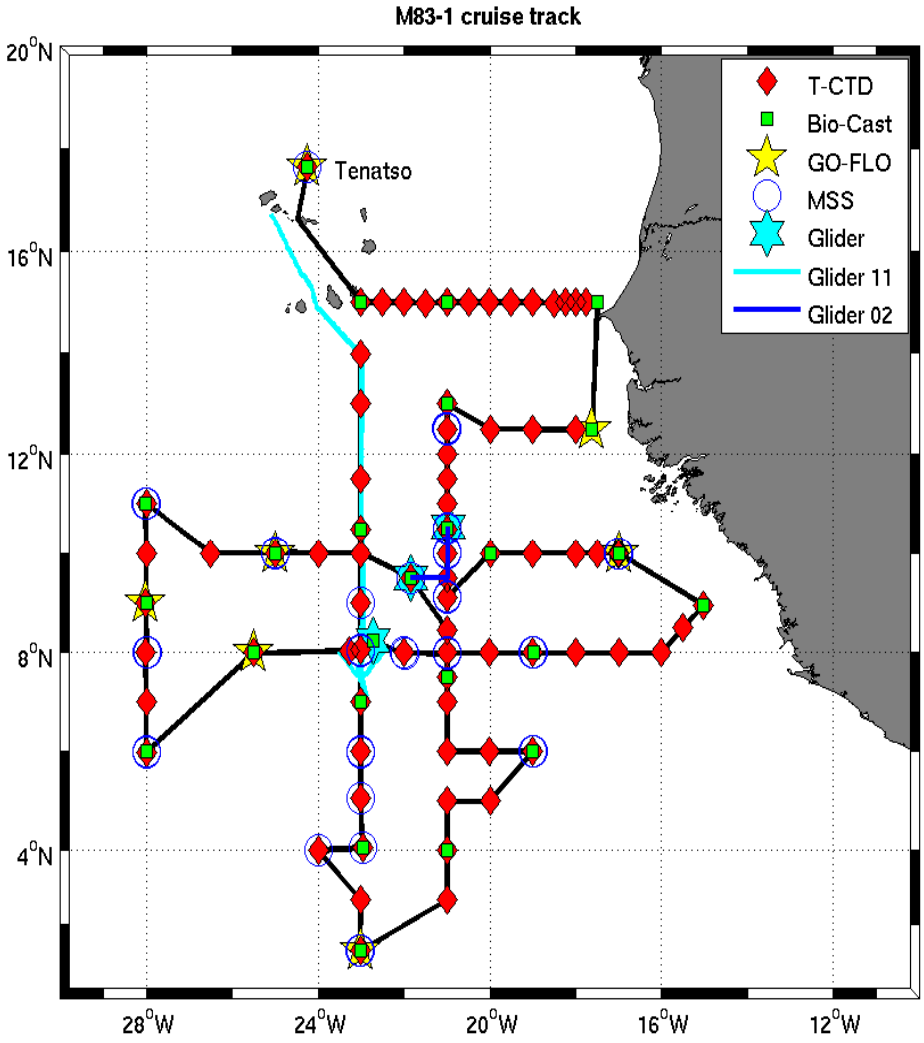

Fig. 3.1 Cruise track of Meteor cruise M83/1.

4 Narrative of the Cruise

October 13: Embarked on METEOR, unpacked containers and began to install equipment in laboratories.

October 14: 10:00 Vessel left port with calm winds, safety and security information were given including life boat drill. Continued to ready science equipment. Transit to Moroccan shelf.

October 15: 8:00 Shifted vessel time to UTC. All day echo sounder system tests near 24°N 16°53W in roughly 600m deep water. Back on transit southward in the evening.

October 16: 8:30 Tested CTD and Test GO-FLO station in the morning. Most systems worked well right from the start. 16:00 SeaPath calibration line 10nm backtracking.

October 17: Transit to TENATSO. Arrived 23:20 at 17°39'N 24°15'W and began with GO-FLO station. Kevlar winch system did not record meter out reliably.

October 18: First Microstructure Sonde profiles. Followed by a GO-FLO. Then CTD to the bottom followed by plankton net. At 6:30 am released PIES #165. 8:00 PIES on deck in good condition. GO-FLO winch wire out meter still broken. Mayor winch problem during third GO-FLO cast with samples deep waiting for the winch repair. Left TENATSO at 12:30 pm for some final echo-sounder checking enroute to Praia.

October 19: Arrived before Praia harbor and Mr. Aase and Mr. Eriksen left METEOR. At 13:20 the first CTD survey section along 15°N began at 23°W with a station spacing of a half degree longitude. CTD stations came every 4 hours and all sampling and analysis systems performed normally. Shipside was working in W1 winch system.

October 20: Continued section along 15°N with CTD stations roughly every 4 hours. In the evening we added the LADCP system to the CTD for the eastern boundary current signatures.

October 21: In the morning squall lines brought heavy rain and strong wind gusts. Reached end point at 17°30W in 500m deep water, LADCP removed. The mesocosm experiments were started after pumping surface water into the 12 chambers. Several short W1 winch tests. Transit south towards the 12°30'N zonal section.

October 22: Bio-CTD and GO-FLO near the shelf at 12°30'N 17°37'W. Small section began towards the west.

October 23: Reached northernmost point (13°N) of a meridional section along 21°N southward. CTD spacing was decreased to 30nm with micro structure stations once in a while. Held a science lecture in the evening about tracers in the sea and also the first results from our cruise.

October 24: Released micro structure glider at 10°30'N and 21°W before lunch. The first couple of shallow profiles looked reasonable. Continued south along 21°W.

October 25: Reached 9°N after Midnight. Short transit to 10°N 20°W and began CTD section to the east along 10°N.

October 26: Reached easternmost station at 17°W and 450m water depth with full sampling including GO-FLO. CTD conductivity sensor #1 developed a problem after the CTD hit the ship in heavy swell and was replaces. Ship ADCP 38kHz was pulled to the surface and rotated to

beams aligned with the ships axis. We expected less interference with the 75kHz system to be determined over the next hours.

October 27: Reached 9°N 15°W on the shelf of Guinea and began the nominal 8°N section towards the west with a BIO cast. The wind picked up in the morning and noticeable swell from different direction rocked the boat significantly. Sampling in the at times heavy showers was not optimal. The weather improved during the day but some of the swell remained and solid trades pushed METEOR with up to 13kn westward.

October 28: Section work at 8°N continued with a morning BIO station at 19°W and several CTD and Microstructure stations for the rest of the day. During the afternoon and night the Ashtech GPS receiver had several 15min long dropouts.

October 29: Arrived near 23°W at 9:30 at the Glider surface spot. Recovery was simple and despite quite a number of barnacles the system looked very good. With 80 days at sea this has been out longest mission of a SLOCUM glider. CTD work continued with a station to the bottom. Unfortunately the winch did not spool cable properly on the way up. Thus we needed to do a second deep cast to get the cable laid properly.

October 30: Section work along 8°N continued. Midmorning we had two short complete power failures on both the stable and unstable networks. This caused many computers to fail, brought the whole ships network down. The station at 25°30' W completed our 8°N transect. We still encountered problems and had to switch CTD deck units to get the system working. After GO-FLO casts in the afternoon a deep CTD cast allowed to improve the spooling of the wire. Our mid cruise party (Bergfest) began with some rain but the weather improved while transiting south.

October 31: We began a northward section at 6°N along 28°W with a 60 nm station spacing.

November 1: At 9°N we planned a deep station. The beginning of the cast was delayed by severe software problem on both CTD deck units. We also failed to transfer our CTD settings to the METEOR based deck unit. Finally we resorted to a much older version of the SeaBird data acquisition software to begin the cast. Despite the water depth of more than 5500m we did not manage to improve the laying of the CTD wire on the W3 winch. Normal tracer CTD stations followed.

November 2: Reached 11°N along 28°W in the morning. Again a power outage/flickers halted the operations for an hour until clean power was restored. Departed 28°W and decided to recover the micro structure glider early because of an abnormal power consumption behavior.

November 3: During the night we began an eastward transect along 10°N. During the GO-FLO station we verified that the W1 winch meter was mostly working with a 8% slower reading compared to the markings and pressure record. We stopped for CTD stations mostly every degree. During a lightning storm in the evening the winch control computer rebooted during the CTD cast. But we were able to complete the cast based on CTD pressure readings.

November 4: At 9°30N and 21°50W we recovered the micro-structure glider during perfect weather conditions. A detailed inspection revealed that water had entered into the micro-rider pressure case. Fortunately the outer part is sealed and separated from the electronic compartment and the 2cc sea water seemed not to have caused damage to the system. We had obtained 5 days

of data before the leak occurred or the amount of water present was enough to cause erratic instrument behavior. CTD stations resumed in the evening on a southward transect along 21°W.

November 5: We continued the 21°W section until reaching 6°N in the afternoon. From there we turned to the east and began a short zonal section along 6°N.

November 6: We reached 19°W in the morning and performed our last deep CTD cast to the bottom in 4600m deep water. As usual the upcast took several hours to complete because the cable had to be laid carefully and often spooling errors needed to be compensated with short pieces of line and tape. The next stations followed a zig-zag pattern to the south west.

November 7: Continued the 21°W section to the south with a station every 60 nm. At 4°N we had only found weak traces of SF5, while at 3°N somewhat more tracer was present. During the day the WTD changed several of the navigation aid systems and the data stream to the ship ADCP system was not perfect.

November 8: Reached at 5:00 am the southernmost station at 2°N and performed full sampling including the last GO-FLO station. The wind was coming from the southeast and we encountered the stronger surface currents from the nearby equatorial current system. The last micro-structure drop resulted in a data transmission error during the recovery. About 200 m cable needed to be cut before a clean signal could be restored. The instrument was ready for deployment in the evening.

November 8-13: Embarked on our last CTD section heading north with the final tracer sampling at 13°N and the last CTD cast at 14°N 23°W. From there transit to the port of Mindelo and we arrived in Mindelo on 13 November at 8:00 am.

5 Preliminary Results

In the following a detailed account of the types of observations, the methods and instrument used as well as some of the early results are given. Several publications are submitted based on the data sets and more are to come.

5.1 Hydrographic sampling

5.1.1 CTD system and salinity

(Lothar Stramma, Gerd Krahmann, Martin Visbeck, Donata Banyte, Rudi Link)

CTD-calibration

During M83/1 a total of 103 CTD-profiles were collected in most cases either to 1200m depth for the surveys of the oxygen minimum layer and the tracer or to 400m for biological sampling. On a number of occasions (close to the continental shelf and near mooring sites) casts were done to full ocean depth (see station list).

During the whole cruise the IFM-GEOMAR SBE#3 with a Seabird SBE 9 CTD rosette system has been used. The CTD system was equipped with one Digiquartz pressure sensor (s/n 82991) and double sensor packages (temperature 1 = s/n 4835, temperature 2 = s/n 4867, conductivity 1 = s/n 3468 (profile 1 to 40), conductivity 1 = s/n 3381 (profile 41 to end), conductivity 2 = s/n 3300, oxygen 1 (sbe 43) = s/n 1314, oxygen 2 (sbe 43) = s/n 0215).

Additionally a new oxygen sensor manufactured by Rinko (s/n 54) in Japan was attached to the system. While this sensor was announced as faster than the regular Seabird oxygen sensors, we found on first sight its response time to be slower. A more in depth analysis of the sensor's data is ongoing at IFM-GEOMAR.

Data acquisition was done using Seabird Seasave software version 7.20b. The CTD was mounted on the GO4 rosette frame with a 24 bottle rosette sampling system with 10 l bottles. In varying configurations 21 to 24 bottles were attached to the rosette. On most profiles a configuration with 23 bottles was used, with one bottle removed for a PAR sensor. On five profiles two more bottles were removed to accommodate a lowered ADCP system. Deep ocean profiles were mostly done with 24 bottles as the PAR sensor had a maximum depth rating of 2000dbar. The final calibration of the CTD data was done using the secondary set of sensors as it remained unchanged during the whole cruise. After profile 40 the conductivity sensor of the primary sensor string failed and was replaced by a sensor from the spare CTD system. The secondary sensor string performed well during the whole cruise. The primary string worked equally well until the sensor change, but the replacement conductivity sensor exhibited significant drift (~0.01PSU over 40 profiles), though it appeared to stabilize towards the end of the cruise.

Short blackouts in the ship's stable power system before CTD profile #57 lead to problems with the acquisition system. For CTD profiles #57, 58, 59, 63, 64 we thus used the backup Seabird deckunit (CTD-DU 01) and acquisition computer. The other profiles were collected on CTD-DU 04. Initially we suspected the switch from Windows XP to Windows 7 to be the root of the problems, but later we discovered that during the computer crashes caused by the blackout, the SeaSave acquisition software left some temporary files under c:\users\... which rendered the software dysfunctional. We will thus report these problems to the manufacturer and develop a batch file deleting these files before starting the acquisition software.

During the postprocessing we also found that the built-in delays for the secondary conductivity sensors were different in the two deck units. CTD-DU 04 had the SeaBird recommended 0.073 seconds for primary and secondary channel, whereas CTD-DU 01 had 0.073 seconds for the primary and 0 seconds for the secondary channel. This discrepancy was corrected later in the postprocessing.

The IFM-GEOMAR Guildline Autosal salinometer #8 was used for CTD conductivity cell calibration (operated by D. Banyte and L. Stramma). The Guildline Autosal salinometer #7 was available as backup, but had not been used. Calibration during operation was done in two ways: IAPSO Standard Seawater (P150, K15=0.99978) was measured at the beginning of the salinometer use. In addition, a so called "substandard" (essentially a large volume of water with constant but unknown salinity), obtained 2 times from deep bottles from the CTD casts was used to track the stability of the system. The substandard showed on a few measurement days a week increasing trend of about 0.0004 in salinity, which was removed from the measured salinity samples. However, on most days the AS8 was stable during the entire measurement time as well as from one measurement day to the next.

A container with 1 m³ of low-nutrient surface water was filled during the cruise and is being shipped to IFM-GEOMAR for use as substandard in the lab.

The conductivity calibration of the downcast data was performed using a linear fit with respect to conductivity, temperature, and pressure (C_corrected = C_observed -0.024078 –

4.4986e-07 * P – 0.00090342 * T + 0.0085635 * C). Using 67% of the 375 samples for calibration a r.m.s. of 0.00026 S/m corresponding to a salinity of 0.0027 PSU was found for the downcast. We chose the downcast as final dataset as: 1) Sensor hysteresis starts from a well defined point, and 2) the incoming flow is not perturbed by turbulence generated by the CTD-rosette.

5.1.2 Oxygen

(Gerd Krahmann, Toste Tanhua, Karen Stange)

Oxygen measurements:
Samples for oxygen determination were taken from a large selection of the tracer-CTDs for calibration of the oxygen sensor of the CTD, and for all bio-CTDs. The oxygen was determined with Winkler titration. The precision of the measurements (1σ) of the oxygen concentration determined from the titration is 0.3 μmol kg^{-1} based of 71 duplicate measurements. The standard solution for the titration was found to be accurate to better than 0.01% based on comparison to two independent reference materials from WAKO inc. (USA). Furthermore, oxygen concentrations in deep water samples were compared to 10 relevant historical cruises in the GLODAP and CARINA databases, and our oxygen data are consistent with both GLODAP and CARINA.

The CTD downcast has been calibrated using 67% of the 1010 data samples and led to an rms difference of 0.92 μmol/kg using a linear correction for temperature, pressure, and oxygen itself (o_corrected = o_observed(μmol/kg) – 0.71825 + 0.0038647 * P + 0.11994 * T + 0.022132 * O).

Early during the cruise we found that the number of strong outliers could be significantly reduced by ensuring that the sample bottle was flushed with at least 3 times its volume. Later during the cruise the deviations between CTD and titration values started to drift away from a fairly constant offset (drift of about 1 to 2 μmol/kg). After changing the chemicals the differences between titrations and CTD were back to 'normal'.

5.1.3 Nutrients

(Toste Tanhua, Kerstin Nachtigall)

Nutrients were measured on-board with a QuAAtro auto-analyzer from SEAL analytics. The following protocols from SEAL analytics were followed:
Ammonia – G-080-06 Rev 2; this is the fluorometric method using o-phtaladehyde.
Nitrite and Nitrate – Q-070-05 Rev 4; The nitrate is determined as nitrite after reduction on a cadmium coil. The nitrite is determined with a colorimetric metric method where sulphanilamide is forming a diazo compound.
Phosphate – Q-064-05 Rev 4; this is the colorimetric method based on reaction with molybdate and antimony ions.
Silicate – Q-066-05 Rev 2; this is the colorimetric method where a silico-molybdate complex is reduced to molybdenum blue.

Samples from the CTD were measured on 912 samples during the cruise. Measurements were performed from all bio-CTDs and a sub-set of tracer-CTDs; all the deep stations, stations along 15°N, 8°N, 28°W, 23°W and 19°W.
The precision of the nutrient measurements were determined from replicate samples taken at a selection of stations. The precisions of the measurements are determined to be: 0.2 µmol/kg for nitrate, 0.05 µmol/kg for phosphate and 0.6 µmol/kg for silicate.

In addition to the CTD casts, samples for nutrients were analyzed from the go-flo casts and from the incubations and meso-cosm experiments.

5.1.4 Measurements of CFC-12, SF_6 and SF_5CF_3

(Toste Tanhua)

During the cruise, two Gas Chromatograph / Purge-and-Trap (GC/PT) systems was used in parallel. The systems are modified versions of the set-up normally used for the analysis of CFCs (Bullister and Weiss, 1988). The two systems (named "PT1" and "PT2") operated and performed slightly different during the cruise, which will be explained below. The trap for PT1 was a 12 cm long 1/8 " SS tube packed with Heysep D; for PT 2 the trap was 100 cm of 1/16" tubing, also packed with Heysep D. The tracers were trapped at -30°C in PT1 and at -60 to -65°C on PT2; desorption at 130°C. For both systems, the pre-column was a 30 cm long Porasil C 1/8" column, whereas the main column consisted of a 200 cm 1/8" column packed with 180 cm Carbograph 1AC (60-80 mesh) and a 20 cm Molsieve 5A tail end. Detection was performed on an Electron Capture Detector (ECD). This set-up allowed efficient analysis of SF_5CF_3 and CFC-12 (that elutes slightly after, but well separated from, SF_5CF_3). Due to slightly differently packed main-columns, the two systems were operated at different temperatures, 50 and 60°C, respectively. Thanks to the lower trapping temperature of PT2, this system was able to measure SF_6 in the samples.

For PT1, samples were collected in 250 ml ground glass syringes, and an aliquot of about 200 ml was injected into the analytical system. For PT2, samples were collected in 1400 ml glass ampoules, and an aliquot of about 1000 ml was injected into the system through a vacuum-sparge technique, similar to that described by (Law et al., 1994).

Standardization was performed by injecting small volumes of two different gaseous standards containing SF_6, SF_5CF_3 and CFC-12. This working standard was prepared by the company Dueste-Steiniger (Germany), and also serves as the reference standard for SF_5CF_3. However, the accuracy of the SF_5CF_3 standard is only accurate to ±10%, and no other reference standards exist today for SF_5CF_3. The CFC-12 and SF_6 concentration in the standards has been calibrated vs. a reference standard obtained from R.F Weiss group at SIO, and the CFC-12 data are reported on the SIO98 scale and SF_6 on the NOAA-2000 scale. Another calibration of the working standard will take place in the lab after the cruise, to determine any possible drift in the working standard. Calibration curves were measured every few days, depending on work load and system performance, to determine the non-linearity of the detector. Point calibrations were always performed between stations to determine the short term drift in the detector.

Replicate measurements were normally run each profile for the PT1instrument. This was only possible on a few stations for PT2 due to the high water demand and long analysis time. On a few stations samples were measured on both systems .The results of the cross-check of the two

instruments relieved no significant biases. Standard deviation of the measurements determined from these replicate measurements, and the detection limits for SF_6, CFC-12 and SF_5CF_3 are listed in Table 5.1.

Compared to the initial survey in the end of 2009, only slightly lower concentrations of the tracer, SF_5CF_3, was found during this cruise. During the cruise, 1553 water samples from 74 profiles were successfully analyzed for its content of CFC-12 and SF_5CF_3. For an example see Figure 5.1.

	System #1 precision	System #2 precision	System #1 Detection Limit	System #2 Detection Limit
SF_6	NA	0.014 fM	NA	0.05 fM
CFC-12	0.01 pM	0.004 pM	0.04 pM	0.4 fM
SF_5CF_3	0.06 fM	0.02 fM	0.1 fM	0.02 fM

Table 5.1 Precision of tracer measurements determined from replicate measurements and approximate limit of detection.

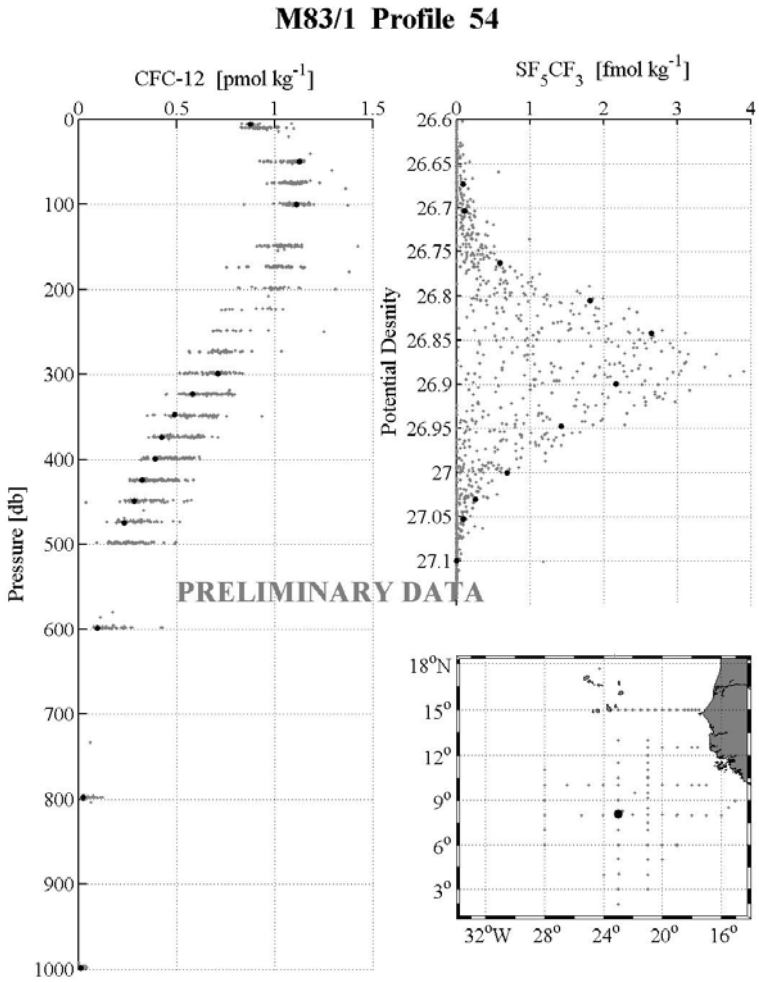

Fig. 5.1 An example of the preliminary SF_5CF_3 concentration vs. density and the CFC-12 concentration vs. pressure. The gray dots represent all data, the black dots the data from profile 54, which is located at the position where the tracer was released 2.5 years earlier. The final data are only slightly different.

The deliberately released tracer (i.e. CF_3SF_5) data has been evaluated, together with data from cruises MSM10/1 and M80/2 (the three cruises during which the tracer distribution was carefully mapped out). Our investigations has (so far) focused on the lateral spreading of the tracer and the estimation of the diapycnal diffusivity constant based on that. We find that the diapycnal diffusivity (D_z) is 1.18 ± 0.13 10^{-5} m^2s^{-1}, or in isopycnic units (D_{rho}) 3.09 ± 0.28 $(kg\ m^{-3})^2\ s^{-1}$. These results are described in Banyte et al., (2012).

The transient tracer data (i.e. SF_6 and CFC-12) data has been evaluated with the Transit Time Distribution (TTD) method. The so derived TTDs have been used to estimate the content of anthropogenic carbon in the area, and to compare to estimate made in 1999. The main result is that significantly higher column inventories of anthropogenic carbon is found in the equatorial belt compared to the Guinea Dome area, a feature that has previously not been described. We also find a significantly increase in anthropogenic carbon in the area that is consistent with the atmospheric increase in CO_2. The results of the transient tracer measurements are discussed in Schneider et al., (2012).

5.1.5 Hydrographic results

(Lothar Stramma, Janin Schaffer)

One objective of the RV Meteor cruise M83/1 was to map the distribution of the OMZ in relation to the water masses and currents in the region of the tracer survey area in the context of the SFB-754. With the large area covered during the cruise, different water mass regimes were covered. Figure 5.2 shows the TS-distribution for the CTD- profiles 2 to 76, covering the eastern tropical North Atlantic between the TENATSO station north of the Cape Verde Islands and 7.5°N. According to a review of the water masses (Stramma et al. 2005) the Cape Verde Frontal Zone north of the Cape Verde Island separates the more saline North Atlantic Central Water from the less saline South Atlantic Central Water in the density range σ_θ=25.8 to 27.1 kg/m^3. Except for the profile at the TENATSO station all other station show a major influence of South Atlantic Central Water. On the low salinity side at temperatures above 15°C in the TS-diagram the coastal stations off Senegal and Guinea are located. Furthermore low salinity water from rain of the Intertropical Convergence Zone at the surface and the subsurface salinity maximum of Subtropical Underwater are well visible. In the Antarctic Intermediate Water visible by the salinity minimum below σ_θ=27.1 kg/m^3 there is a continuous progression to slightly higher salinities indicating mixing on the progression northward.

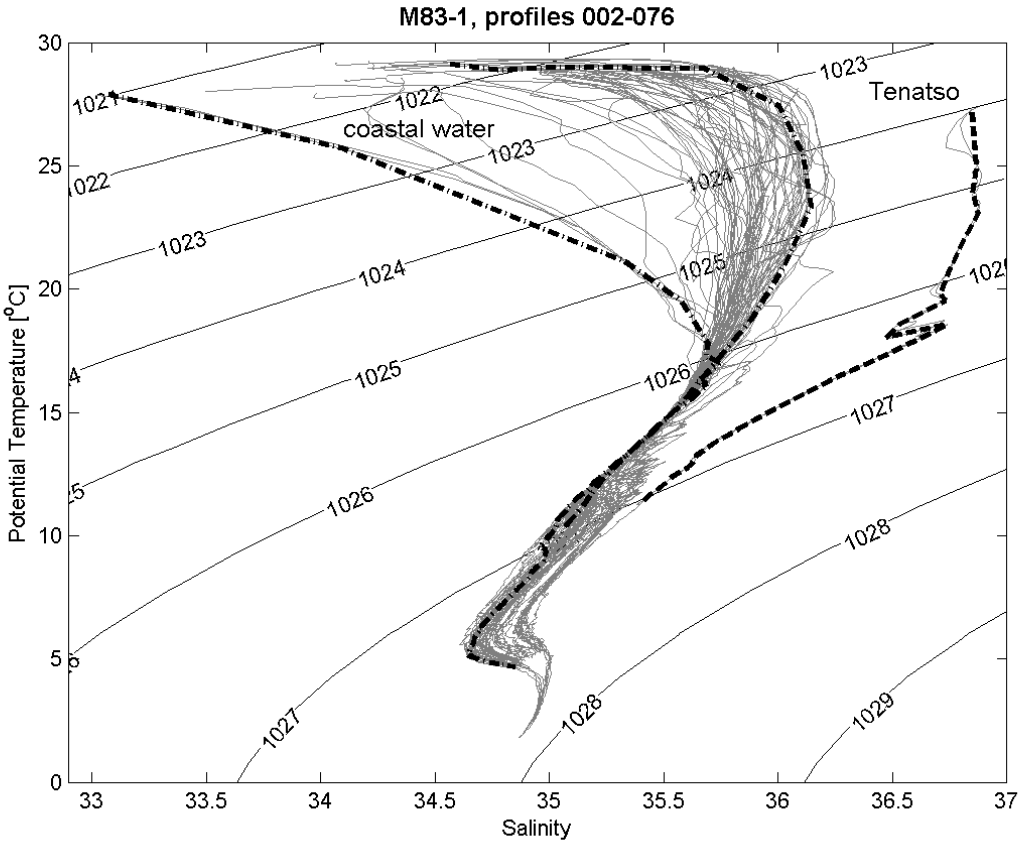

Fig. 5.2 TS-Diagram of the CTD profiles 2 to 76 taken during Meteor M83/1 in October and November 2010. Dashed lines for selected stations for the low salinity region off Guinea at 9°N, 15°W (left dashed line) in the western tropical region 8°N, 28°W (middle dashed line) and at the TENATO station 17.65°N, 24.25°W (right dashed line).

The large scale horizontal distribution of the lowest oxygen value within the OMZ as measured with the CTD oxygen sensor during M83/1 (Fig. 5.3 left) shows the expected distribution of higher oxygen values in the region of the eastward North Equatorial Under- und Countercurrents at 4 to 9°N while in the so called Guinea Dome region and the station closest to the African continent the lowest values were observed. From the Merian cruise tracer survey of this area in late 2008 for the first time record low oxygen values of less than 40 µmol/kg were described (Stramma et al. 2009). The M83/1 2010-survey showed similar low oxygen values reaching values below 40 µmol/kg, however no general further decreasing oxygen values are visible in late 2010 two years after the Merian survey.

The large scale station distribution was carried out to measure the tracer distribution 2.5 years after a tracer was released in April 2008 at about 8°N, 23°W in a 30 x 30 km square on the density surface σ_θ=26.85 kg/m^3 (in the following called target density). The distribution of the largest tracer values found in October/November 2010 resembles well the distribution of the lowest values in oxygen in Figure 5.3 (left). However, the oxygen distribution for the isopycnal target surface (Figure 5.3 right) showed a surprising result. At the tracer release location and west of it the oxygen distribution shows opposite to the distribution of the lowest oxygen values relative high oxygen values, while the station to the east with high tracer recovery showed low oxygen values. The reason is that at the depth of the target isopycnal at the release site eastward

currents carry relative oxygen rich water eastward, and the tracer was released into water with relative high oxygen which mixes with low oxygen water on its way east leading to reduced oxygen values when transported east, while it stayed at high oxygen values when progressing westward within the oxygen rich water. Hence the oxygen distribution at the target density shows a different behavior than in the oxygen minimum core about 100 to 150 m below.

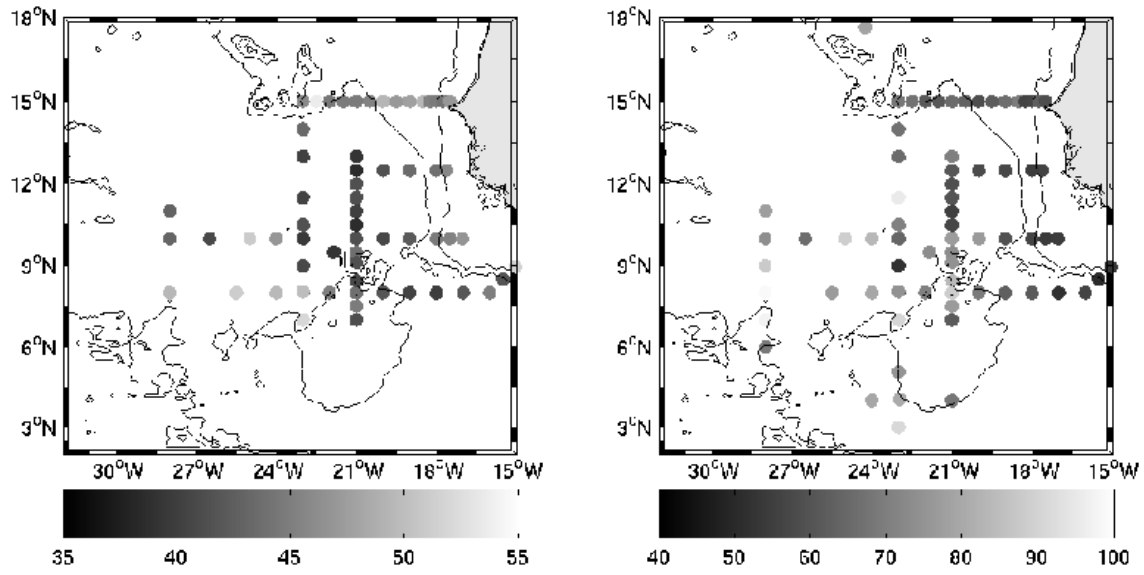

Fig. 5.3 Distribution of the lowest oxygen minimum values in µmol/kg in (left) the oxygen minimum layer at 300 to 600 m depth and (right) on the isopycnal surface 26.85 kg m^{-3} from M83/1 CTD stations in October and November 2010.

One aim of the SFB-754 is to investigate possible changes in the OMZ and some recent literature results indicated decreasing oxygen levels during the last few decades. For a direct comparison between the November 2008 RV Merian cruise and a part of a WOCE cruise carried out by RV Atalante in March 1993 along 7.5°N a decrease of the lowest oxygen values in the oxygen minimum could be shown (Stramma et al. 2009). Here we compare the RV Merian section from November 2008 with the Meteor M83/1 section at 8°N in October 2010 (Figure 5.4). The isopycnal σ_Θ= 27.1 kg/m^3 marks the boundaries between the South Atlantic Central Water (SACW) and the Antarctic Intermediate Water (AAIW). The oxygen minimum is located in both water masses with the minimum in the lower reaches of the SACW. In addition the tracer target isopycnal σ_Θ= 26.85 kg/m^3 is included in Figure 5.4(a and b). This target isopycnal shows the fact described above, that this isopycnal is located at relatively high oxygen values in the west and the oxygen values decrease eastward. The lowest oxygen values reached on both sections is plotted in Figure 5.4c. As in 2008 low oxygen values at or below 40 µmol/kg are reached in the east also in 2010. However, no further decrease in oxygen can be determined. The reason might be either that the time period is too short and the distribution is influenced by seasonal variability or the fact that the two sections are not exactly at the same latitude might bias the result.

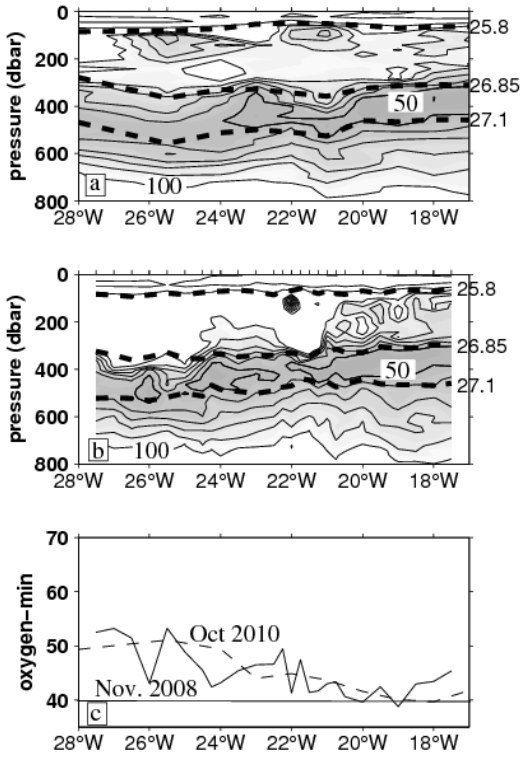

Fig. 5.4 Dissolved oxygen section along 8°N with 10 µmol kg^{-1} contour intervals below 100 µmol kg^{-1} and 50 µmol kg^{-1} contour intervals for oxygen larger than 100 µmol kg^{-1} for a) October 2010 along 8°N and b) data from November 2008 along 7.5°N. The isopycnals σ_θ=25.8 and 27.1 kg/m^3 are included as dashed lines which mark the boundaries between Tropical Surface Water and the South Atlantic Central Water (SACW) and between the SACW and the Antarctic Intermediate Water. The isopycnal σ_θ=26.85 kg/m^3 represents the target layer of the tracer survey. The lowest oxygen values reached in the depth range 300 to 600 m are shown in c) for October 2010 (dashed line) and November 2008 (solid line) with 40 µmol kg^{-1} marked as line.

5.2 Biogeochemical sampling

5.2.1 N_2-fixation and nitrous oxide production

(Carolin Löscher)

Dinitrogen fixation along vertical oxygen and nutrient gradients

Dinitrogen (N_2) fixation is a biological process carried out by prokaryotic organisms, known as diazotrophs. This process plays a key role for maintaining biological productivity in the oceans (Capone, 2008; Deutsch et al., 2007) and represents the input mechanism to the marine nitrogen cycle. Preliminary results of the mesocosm experiments suggest a nitrogen limitation of primary productivity in the investigated area constituting a possible niche for diazotrophs (Mills et al., 2004), there.

In our study, the community structure of diazotrophs and their activity and thus the overall input of new nitrogen into the ecosystem were investigated. The direct (O_2) and indirect (N/P) effects of O_2 on rates of N_2-fixation and the functional gene diversity of diazotrophs was examined using a variety of approaches ranging from vertical profiles of N_2-fixation via $^{15}N_2$ fertilization to nutrient addition experiments in collaboration with the mesocosm group. Therefore, triplicate 4.5L samples were taken from two to five depths from the CTD and

incubated for 24h in either on deck incubators or in the cold room at approximately in situ temperatures after the new method described in Mohr *et al.,* 2010. To compare dinitrogen fixation to primary production, $H^{13}CO_3^-$ addition experiments were performed along with the $^{15}N_2$ incubations. A total of 18 experiments were performed. Samples will be analyzed using mass spectrometry.

The dominating diazotroph was *Trichodesmium sp.* in large parts of the investigated area with abundances of up to 10^8 *nifH* copies L^{-1}. The full dataset is available on the SFB754 database.

Ammonia uptake/ Nitrous oxide (N_2O) production along vertical profiles

Nitrogen turnover processes in the eastern tropical North Atlantic Ocean (ETNA) are dominated by nitrification due to relatively high oxygen saturations in the water column of the ETNA. A potential role of decreasing oxygen conditions for the production of nitrous oxide was investigated using incubation experiments.

Information on the in situ production of the greenhouse gas N_2O via nitrification in the environment is so far relatively sparse. To identify the source and rate of N_2O in the ETNA, 24h incubations of small volume (25mL) seawater samples were performed along oxygen gradients at 5 stations during M83/1. Additional information of ammonia uptake rates, isotopic composition and producing organisms were obtained by adding defined amounts of $^{15}NH_4^+$ and archaeal inhibitors to the incubations. Measurements and evaluation of N_2O samples took place in the labs of Hermann Bange and Ruth Schmitz-Streit. N_2O production could mainly be ascribed to archaea in OMZ waters. Highest rates of up to 2 nmol L^{-1} d^{-1} were detected in the core of the OMZ. The complete dataset is available on the SFB754 database.

In order to identify the distribution of N_2O in high resolution, N_2O samples were taken in triplicates in 25ml glass vials, crimped airtight and conserved by $HgCl_2$ addition followed by gas chromatographic detection. As many additional measurements as possible were performed in parallel to the N_2O sampling: gene abundance, CTD, microstructure profiles, ADCP, oxygen, F12, nutrients.

5.2.2 Sampling of DNA/RNA

(Carolin Löscher)

Metagenomic/ -transcriptomic and chlorophyll sampling

A total of 600 samples for DNA/RNA and 700 samples for chlorophylls were taken from the daily Bio-CTDs as well as from additional selected Tracer CTD profiles. Chlorophyll was analysed directly on board by fluorometry, the full dataset is available on the SFB 754 database. Small volume DNA/RNA samples (~2L) were filtered through 0.2µm membrane filters (Millipore, Isopore membrane filters) within a time frame of 20min after collection from the CTD to prevent temperature and light responses in the RNA. Filters were immediately frozen and stored at -80°C until analysis in the home labs.

DNA/RNA samples were analysed regarding microbial diversity and gene activity in the lab of Ruth Schmitz-Streit. The microbial gene diversity was analysed, especially with regard to genes involved in the marine nitrogen cycle. Key N_2-fixers were closest related to *Trichodesmium sp.*, to *y*-Proteobacteria and DDAs; sequences are available via MG-RAST upon

request until publication. A newly developed microarray has been used to screen for N- cycle genes, results have been verified by quantitative Real Time PCR and sequencing.
The phylogenetic diversity of 16S rDNA, the *nifH* and the *amoA* has been monitored. Hereby, the main focus has been set on the composition of the microbial and in the water masses marked by the SF_5CF_3- tracer brought out in April 2008 (cruise MSM 8/1) to be able to follow changes in microbial communities over time.

A metagenomic and metatranscriptomic approach will be further used to determine the extent to which phylogenetically-related diazotroph ecotypes as well as other microbes involved in the nitrogen cycle are adapted to specific nutrient stoichiometry and O_2 concentrations.

5.2.3 Sampling of phytoplankton pigments, biogenic silicate and dissolved/particulate organic matter

(Jasmin Franz)

High resolution sampling for a series of biogeochemical parameters along transects was carried out during the cruise. Daily BIO-CTD casts (25 in total) which focused on the upper water body (max. depth 400m) were used to sample for dissolved and particulate organic compounds (C, N, P). Their distribution in combination with the distribution of inorganic nutrients (see 5.1.3) will allow assessment of nutrient regeneration compared to apparent oxygen utilization (AOU) associated with organic matter remineralisation. Furthermore, samples for the determination of phytoplankton pigments via HPLC (High Pressure Liquid Chromatography) measurement were taken. The detection of diagnostic pigments will help to obtain an impression about the composition of the phytoplankton community along gradients of nutrient availability. Biogenic silicate is an indicator for the occurrence of diatoms, therefore its analysis will specifically help to understand the distribution of this very important microalgae. Lugol-fixed samples for microplanktonic counts and samples for fatty acid composition of seston were additionally taken from the chlorophyll a maximum in order to investigate the taxonomic and elemental composition of this community.

In addition to the BIO-CTDs, selected Tracer CTD casts (18 in total) were also sampled for POC/PON, DOC and phytoplankton pigments.).

For sampling, water was filtered onto combusted (450°C for 5h; POM) or not combusted (pigments) glass fibre filters (0.7µm pore size, 25mm diameter), or cellulose acetate filters (0.65µm pore size, 25mm diameter; BSi) at low vacuum pressure (< 200mbar) and immediately stored frozen at -20°C (POM, BSi) or -80°C (pigments) until analysis at the IFM-GEOMAR.
Water samples of ca. 20ml were filled into combusted (450°C for 12h) glass vials and immediately stored frozen at -20°C for measurement of DOC.

For the analysis of dissolved organic nitrogen (DON) and phosphorus (DOP) according to Koroleff (1977), one portioning spoon of the oxidation reagent Oxisolv (Merck) was dissolved in approximately 40 ml of sample and autoclaved in a pressure cooker for 30 minutes. 10 ml of the oxidized sample was added to 0.3 ml of a mixed reagent (4.5 M H_2SO_4 + ammonium molybdate + potassium antimonyl tartrate) and 0.3 ml of ascorbic acid, incubated for 10 minutes and finally the content of total dissolved phosphorus (TDP) was determined colorimetrically at 882 nm against double deionized water. In order to receive the DOP concentration, phosphate was subtracted from the TDP value.

DON was detected by pumping the oxidized sample through a reductor containing cadmium, resulting in the reduction of all dissolved organic nitrogen compounds to nitrite. After an incubation of 30 minutes, total dissolved nitrogen (TDN) was measured with a spectrometer at a wavelength of 542 nm against double deionized water. Subtraction of the dissolved inorganic nitrogen (DIN), including NO_2^-, NO_3^- and NH_4^+, delivered the DON concentration.

5.2.4 Sampling of zooplankton to determine nutritional condition (RNA/DNA), stable C and N isotopes, and excretion rates (NH_4 and PO_4)

(Helena Hauss)

On all BIO-CTD stations (25 stations), Zooplankton net hauls were conducted before or after the CTD casts were completed, using a WP2 nets with a mesh size of 150µm which was hauled vertically from either 50m (night) or 100m (day) to the surface. Three copepod target species (*Euchaeta marina, Undinula vulgaris* and *Scolecithrix danae*) that were abundant on all stations were sampled. Adult females were sorted alive, immediately frozen at -80°C for determination of their RNA/DNA ratio (as a proxy for nutritional condition), or dried overnight for stable isotopes of C and N (as a proxy for atmospheric fixed N_2 in the food web) and contents of carbon, nitrogen and phosphorus. From the Chl-a maximum of the corresponding CTD cast, a lugol-fixed 250ml sample was collected for microscopic identification/counting of phytoplankton, and 1 L was filtered on precombusted 0.2µm GF/F filters and frozen at -80°C for analysis of the fatty acid composition of the phytoplankton.

On five stations, ammonium (NH_4) and phosphate (PO_4) excretion experiments were conducted using the three aforementioned species. Adult females (n=3 to n=8) were incubated in three replicates in 0.2µm filtered seawater in 500ml Kautex bottles at two temperatures (11 and 23°C). Concentrations of ammonium and phosphate were determined at four sampling times using a Quattro autoanalyzer (see Nutrient section 5.1.3) and triplicate measurements; a blank (bottle without copepods) was included in every measurement and used to correct the values for background concentrations..

Copepod ammonium excretion (Figure 5.5) revealed a 2.5 – 5fold difference in excretion rate between the two experimental temperatures. Additionally, it is suggested that, at least at the warmer temperature, excretion is nonlinear, meaning that relatively large amounts are excreted within the first few hours after feeding. In context with the low rates at low temperatures, relatively small amounts of ammonium may be exported to deeper water layers by diel vertical migration (DVM).

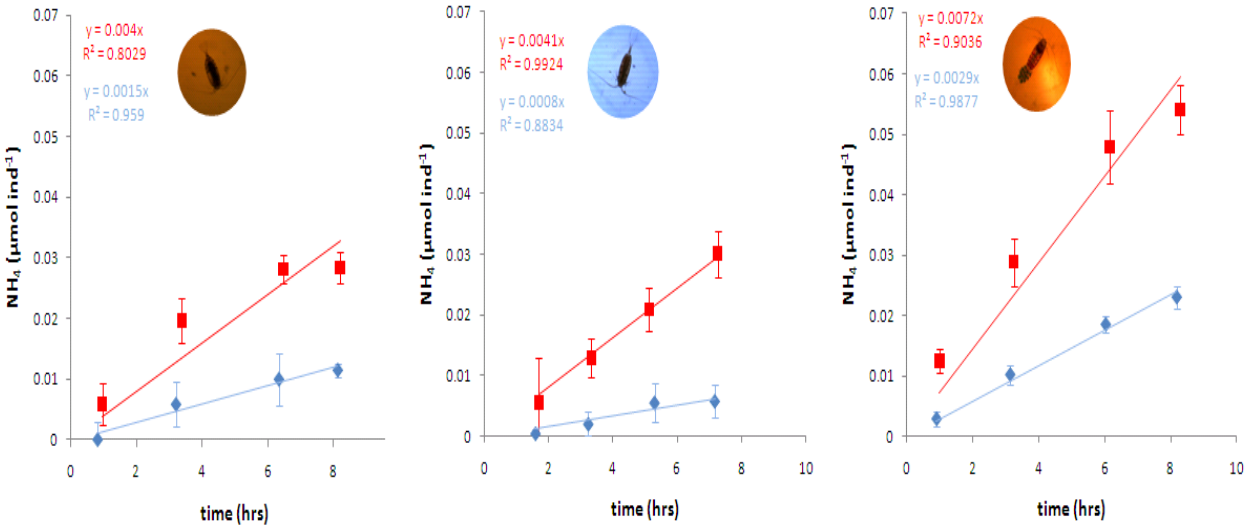

Fig. 5.5 Ammonium excretion (µmol ind^{-1}) of three copepods (left: *Scolecithrix danae*, middle: *Undinula vulgaris*, right: *Euchaeta marina*) at two temperatures (11°C, blue diamonds, 21-24°C, red squares). Values are treatment means (n=3), error bars denote standard deviation. Linear regressions are fitted through the origin.

5.3 Irradiance effects on surface ocean biogeochemical processes and trace metal speciation

(Maija Heller (University of Southern California), Kathrin Wuttig, Peter Croot (National University of Ireland, Galway))

Introduction

While much recent marine trace metal work has focused on the role of iron on ocean productivity, it is now clear, through at sea incubation experiments and laboratory studies, that other elements like copper (Cu) and Manganese (Mn) also play a role in controlling the species composition of the phytoplankton and can impact the rates at which macronutrients are utilized. These changes in rates of uptake are then reflected as differences in the nutrient ratios, or metal to nutrient ratios, of the phytoplankton and impact the observed Redfield ratios in the surface water. A further complicating factor is the chemical speciation and bioavailability of these bio-elements may also undergo changes as a function of phytoplankton growth.

Copper is an important component of respiratory proteins and oxidases and as such is a required element for phytoplankton. However even at the low level of free copper ($Cu^{2+}{}_{f}$) concentrations found in the environment (pM to nM), cell division rates of phytoplankton in culture have been shown to be dramatically reduced, particularly for cyanobacteria. Elevated free Cu^{2+} in phytoplankton cells can decrease photosynthetic rates, competitively inhibit the uptake of other essential metals such as Mn and disrupt enzyme function through binding to thiol groups(-SH) or from reactions with oxygen species to from the damaging hydroxyl radical.

Mn shows a contrasting behaviour to Cu, but they are linked through shared processes. Mn^{2+} and Cu^{2+} share the same metal uptake system in most phytoplankton with the toxic Cu^{2+} strongly

favoured over Mn^{2+} by non-specific transporters. Cu and Mn differ greatly in their speciation in the open ocean with Mn present mostly as the Mn^{2+} aquo ion, while Cu is dominated by strong organic Cu complexing ligands. The two metals also differ in their redox cycling in the surface ocean as particulate MnO_2 can be photoreduced to produce soluble Mn^{2+} which is slowly oxidized back to Mn^{4+} via Mn^{3+}.

H_2O_2 is a short lived photochemically produced trace oxidant found throughout the water column but predominantly in sunlit surface waters. Information on H_2O_2 concentrations allows us to constrain the oxidation time of reduced metal species (e.g. Cu(I), Fe(II)) in the ocean where H_2O_2 can be the principal oxidant, this information is important for understanding the biogeochemical cycling of these metals. Additionally the superoxide (O_2^-) radical is suspected to be a critically important species involved in the redox cycling of metal ions in natural waters. Inorganic and organic complexes of Cu and Fe can react rapidly with O_2^- leading to a catalytic cycle.

O_2^- and H_2O_2 are principally produced in the water column by photochemical reactions involving coloured dissolved organic matter (CDOM) and O_2. In the open ocean CDOM is produced by heterotrophic processes in the upper water column and is destroyed by solar bleaching. Key components identified in CDOM include humic and fulvic acids which can also form complexes with trace metals. Overall there is currently a lack of data worldwide for the CDOM properties of different oceanic regions. For M83/1 CDOM data were collected to assess its role in the production of H_2O_2 and O_2^- in the sunlit surface waters and to determine possible changes in CDOM optical properties in the OMZ of the western tropical Atlantic as the humic components of CDOM are typically strongly related to the Apparent Oxygen Utilization (AOU) and may provide an additional tracer of remineralization processes and oxygen consumption.

The inorganic iodine species, Iodide (I^-) and Iodate (IO_3^-), can be used to study redox processes in the ocean as there redox couplelies between that of oxygen and the reduction of nitrate. Intermediate iodo-organic species (e.g. Methyliodide) are formed by reaction of the inorganic iodide species with organic matter) and are important climatically relevant trace gases in the atmosphere which are released to the atmosphere via air/sea gas exchange.

Water Sampling

Seawater sampling for the study of trace metals was performed using 4 Teflon coated 8 L PVC General Oceanics (Miami, Florida, USA) GO-FLO bottles. The bottles were deployed on the Kevlar line winch W1 of R.V. Meteor. During the cruise transect, two types of GO-FLO casts were performed one down to 80 meters and a deeper cast to 400 meters. Bottles were immediately transferred into the IFM-GEOMAR clean container (Class 5 HEPA filtered air environment). Seawater was filtered with a small overpressure (0.2 bar) of nitrogen on Sartobran (Sartorius, Germany) Membranes (0.2 µm) directly connected to the bottles. Samples for Iodate were filtered and the samples immediately frozen at -20°C. They will be shipped to shore for later analysis. For the direct measurement of the short lived species Fe(II), H_2O_2 and also CDOM, contamination problems are less relevant than for other trace metals and samples for these parameters have therefore also been sampled from the CTD rosette system.

Data Archiving

Data collected during M83-1 will be archived within the IFM-GEOMAR SFB754 or SOPRAN database once finally analyzed and checked for quality.

5.3.1: Influence of irradiation on trace metal redox cycles.

5.3.1.1: Examination of the distribution of H_2O_2 and Fe(II) in the water column of the Atlantic Ocean

Introduction

Numerous studies have shown that Fe(III) is strongly organically complexed in seawater and also more recently that the reduced form, Fe(II), may be an important species within the photic zone. Fe(II) can be formed via photoreduction of iron colloids or particles and more likely via the direct photoreduction of Fe(III)organic complexes. Though inorganic Fe(II) is rapidly oxidized in warm water by O_2 and H_2O_2 it is not yet clear how important organically complexed Fe(II) may be as an iron pool in surface waters.H_2O_2 is the most stable intermediate in the four-electron reduction of O_2 and H_2O and may function as an oxidant or a reductant.

Methods

Simultaneous measurements of H_2O_2 and Fe(II) in the water column.

For this work we employed a new technique developed at the IFM-GEOMAR which uses an established flow injection system in which both species, H_2O_2 and Fe(II), can be measured simultaneously in one sample. Samples were analyzed within 1-2 hours of collection where possible and were not filtered.

H_2O_2 was measured using a slight variation of an earlier flow injection chemiluminescence (FIA-CL) reagent injection method (Yuan and Shiller 2001). Fe(II) was measured using an adaptation of a method developed earlier (Croot and Laan 2002).

Preliminary results

Below are shown 2 examples (Figure 5.6) for vertical profiles for H_2O_2 measurements- one for the Tropical Eastern North Atlantic Time Series Observatory (TENATSO) (CTD Stn 5) and one for the shelf station (CTD Stn 41). The station at TENATSO indicates that there was a relative low surface concentration of H_2O_2. In the depth of a small but significant increase could be observed. GO-FLO station 3 showed high values for H_2O_2 in the surface waters but this suddenly decreased in the top 100m.

Where a major phytoplankton bloom is occurring H_2O_2 concentrations are elevated in the surface waters which is typical found in Tropical regions. The possible reasons for this include (1) release of large amounts of photolabile DOC by the phytoplankton due to senescence or (2) direct biological production of H_2O_2 by phytoplankton cells. Deep water profiles often showed elevated H_2O_2 and it is thought that these may be related to enzymatic reactions associated with the remineralization of organic matter that occurs at this depth.

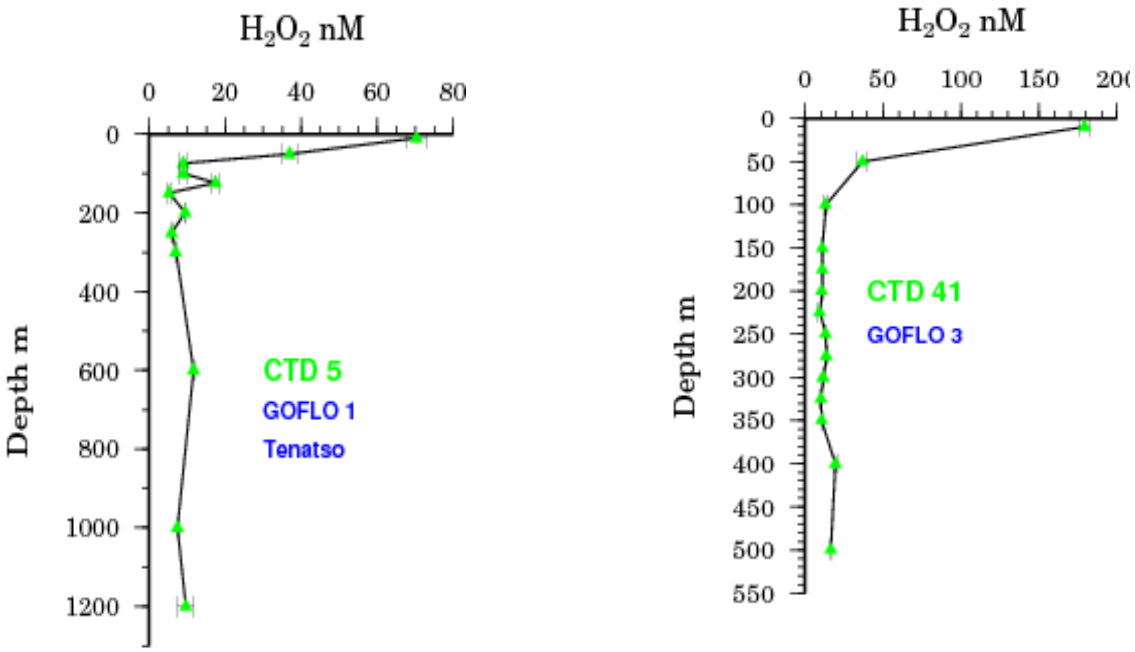

Fig. 5.6 H2O2 vertical profiles from TENATSO (GO-FLO station 1) and the shelf GO-FLO station 3. Error bars are shown for the 95% confidence interval.

5.3.1.2 Distribution and properties of Coloured Dissolved Organic Matter (CDOM)

Introduction

CDOM plays an important role in light availability for primary productivity and for photochemical reactions where it is critical to the production of free radical species. CDOM strongly absorbs light, most notably in the biologically damaging ultraviolet (UV) B wavelengths (280–320 nm), and thus provides some protection for phytoplankton and other biota. CDOM can also attenuate the photosynthetically active radiation available to phytoplankton, resulting in decreased primary production.

Methods

Samples for CDOM fluorescence and absorbance measurements were syringe filtered through 0.2 µm filters (Sarstedt). The first 10 mL were always discarded due to contamination issues of the filters. 3D CDOM fluorescence measurements were performed with a Cary Eclipse Flourecence Fluorometer (Varian) using a 1cm quartz cell. Excitation wavelengths were scanned (12000 nm/min) from 250 to 500 nm (5 nm slit width and 5 nm increments) and emission wavelengths from 240 to 600 nm, the PMT voltage was set at 700 V and the response time 0.08 s. The resulting data matrix is subject to parallel factor analysis (PARAFAC) to determine the relationships between the fluorescence of the sample and its components. Sample fluorescence

was normalized to daily measurements of standards of quinine fluorescence (QSU) or to the Raman induced fluorescence of water.

CDOM absorbance measurements were performed using a LWCC-2100 100 cm path length liquid waveguide cell (World Precision Instruments, Sarasota, FL, USA) and an Ocean Optics USB4000 UV-VIS spectrophotometer in conjunction with an Ocean Optics DT-MINI-2-GS light source. The resulting dimensionless optical density spectra were converted to absorption coefficient (m^{-1}): $a_{CDOM(\lambda)} = 2.303\ A_\lambda / \ell$, where 2.303 converts decadal logarithmic absorbance to base e, and ℓ is the effective optical path length of the waveguide.

The combination of PARAFAC modeling and $a_{CDOM(\lambda)}$ can be used to identify purely statistical fluorophore components that are responsible for specific regions.

Preliminary results

Investigation of CDOM data showed in OMZ waters at least 4 distinct regions in the vertical data. (i) Bleached surface waters with low absorbance coefficients at 300 nm. (ii) A region around 50-100 m with high absorption at 300 nm presumably related to production of new organic material by phytoplankton. (iii) A deeper high absorbance (300 nm) region consistent with the OMZ which may be related to decomposition of sinking organic material. (iv) Uniform absorption coefficient (300 nm) values in the deep ocean.

5.3.1.3 Examination of the different reaction pathways of Superoxide (O_2^-) with the biorelevant trace metals Fe, Cu, Mn and with organic matter

Introduction

The overall aim of our study is to assess the role of O_2^- in the redox cycling of the important biorelevant trace metals Fe, Cu, Mn in the Tropical Atlantic. In the present work we also examined the organic (non-metal) pathways for superoxide decay in seawater in order to better understand other key pathways for O_2^- loss in seawater. This is the first study that we are aware in open ocean waters that focuses on the relationship between CDOM and the organic reactions with O_2^- in seawater combined with the extensive examination of all presently known reaction pathways with trace metals.

Methods

For this work, we employed a chemiluminescence analysis method for O_2^- utilizing MCLA using a commercially available FeLume (Wateville Analytical) system modified by our previous work (Heller and Croot 2010).

For this work 2 different sources of O_2^- were used (KO_2 and SOTS-1 (bis(4-carboxybenzyl)hyponitrite)) in order to determine the concentration and production rate of O_2^- in seawater. Experiments at different temperatures were conducted to examine the production of O_2^- from SOTS-1 and the influence of temperature on the half life of the radical species. Ultrafiltration of seawater samples was conducted in order to examine the influence of different size fraction species on the reactivity of O_2^-.

Preliminary results

In this work we could successfully employ KO_2 but also the superoxide thermal source SOTS-1 which we had previously found in our laboratory studies as a reliable source of O_2^-. The

thermal decomposition of SOTS-1 in seawater was also evaluated over different temperatures. The fractions of ultrafiltered seawater show a different reactivity with O_2^- which indicates an important influence of the size fraction of the present reactive compound in the sample. The reduced lifetime of O_2^- was like expected from our previous work dominated by the reaction with Cu but also Fe and Mn showed a significant reaction throughout the water column.

5.3.1.4 Detection of the redox sensitive species Iodate (IO_3^-)

Introduction

Relatively little is known about the specific drivers of the I^-/IO_3^- cycle but it is now clear that it is mostly controlled by biological processes for both the oxidation and reduction pathways. In OMZs however it is found that the reduction pathway dominates and oxidation is extremely slow but the mechanisms for these transformations are not well understood up to now.

Methods

The samples will be measured for Iodate at NUI Galway either by Voltammetry or by a spectrophotometric method.

5.3.2 Trace metal speciation in the tropical Atlantic Ocean.

5.3.2.1 Distribution of Manganese (Mn) in the tropical Atlantic ocean

Introduction

Manganese can be supplied to the surface waters of the open ocean by a variety of natural pathways: Atmospheric deposition, advection of suspended material from coastal regions, upwelling and mixing from deep water. Manganese is a key metal for photosynthesis due to its unique role in photosystem II. It is also used in the other redox enzymes such as superoxide dismutase. At low level of free Mn phytoplankton growth rates are reduced, but at ambient seawater concentrations Mn limitations is still yet to be clearly demonstrated.

Methods

Dissolved Manganese (dMn) was measured in filtered and acidified (pH 1.7) seawater. dMn was measured by a sensitive flow injection analysis and spectrophotometric detection after activation with Nitrilotriacetic acid (NTA) and reaction with Leucomalachite green (LMG) and Periodate following the method developed by Aguilar-Islas et al. (2008) and enhancing the sensitivity by cambining the method with a 10cm longpath cell.

Preliminary Results

Figure 5.7 shows the Manganese profile from the ocean open station TENATSO. Higher concentrations could be detected at the surface with a subsurface maximum around 50m. Also the deepest sample showed a slightly higher value. This data proves the different supply pathways by atmospheric input and sediments.

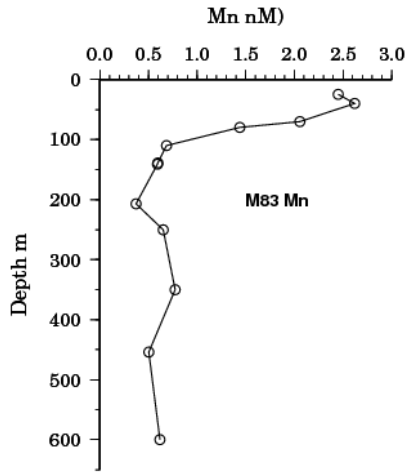

Fig. 5.7 Vertical profile of dissolved Manganese at TENATSO.

5.3.2.2 Cu speciation in open Ocean and shelf waters of the tropical Atlantic Ocean

Introduction

Dissolved copper in seawater has been found to be efficiently complexed by strong organic ligands, of unknown functionality, but believed to be biologically produced. This organic complexation of Cu greatly reduces the free copper concentration to below 1 pM in most open ocean waters and unpolluted coastal waters, a level at which most phytoplankton are not Cu stressed. It has been suggested that some of the weaker copper organic complexes in seawater released by copper stressed phytoplankton may be thiol containing complexes.

Methods

Copper speciation measurements were made using the ligand Salicylaldoxime (SA) with the voltametric method of (Campos and Vandenberg 1994). For each station 6 samples from throughout the water column were analysed using two detection windows (2 µM and 5 µM SA). The data was analysed using a non-linear optimization of a Langmuir isotherm (Gerringa, Herman et al. 1995).

Preliminary results

In general we found stronger complexation in surface waters than in deeper waters. Surface water samples had an excess of metal complexing ligands. The complete data set will be analysed once the samples for Total Cu are analysed in the laboratory in Kiel.

5.4 Current Observation

5.4.1 Vessel mounted ADCP

(Gerd Krahmann and Martin Visbeck)

RV METEOR is equipped with a hull mounted RDI OceanSurveyor ADCP of 75 kHz and a sea-well mounted RDI OceanSurveyor ADCP of 38 kHz. For almost the entire cruise both were operative for underway current measurements. There were, however, some problems with the setup of the two systems. This was partly caused by a new 38 kHz system installed during the

last ship maintenance and partly by a new integrated navigation system installed at the same time. We found that in difference to the previous 38 kHz system, the new one was installed with its beams at 45 degrees to the ships heading. This was done in accordance with the manufacturer's instructions. These instructions did, however, not take care of the case of a contemporaneous 75 and 38 kHz setup. The result was interference of the 38 kHz system into the 75 kHz system. After the problem was recognized, the 38 kHz system was raised in the sea-well and rotated to have one beam in the ship's direction (0 degrees offset). While this is not optimal for high ship speeds, seldom reached on research vessels, the interference between the two systems was totally removed (see Figure 5.8).

Navigational data directly available for the ADCP system was mostly supplied from the integrated SEAPATH-system: GPS-position and heading calculated from 2-dimensional GPS and gyros.

There was no synchro heading fed to the ADCP deck unit. In order to have more than one source of heading information and to have a consistent navigation data set, unprocessed heading output from the FibreOpticGyro as well as all other navigation systems was stored via the DAVISShip database.

Later in the cruise, the ship's integrated navigation system (SEAPATH) developed a problem that resulted in short navigation outages of the ADCPs. The subsequent fix created more problems for the ADCPs as the navigation data arrived only in irregular intervals. A secondary navigation system was then fed into the ADCPs with good results. Even later the navigation system of the ship was again modified to fix possible problems with the Kongsberg echo sounders and the old (before shipyard maintenance) Ashtec ADU data was fed into the ADCPs. This again resulted in problems as the ADCPs software (VMDAS) did not recognize heading, pitch, and roll fed into the computers. As all of the navigational data is stored by the ship's computer systems we intend to extract a consistent navigation data set after the cruise and reprocess the ADCP data.

To avoid acoustic interferences, it was also necessary to have the on-board 75 kHz Doppler Velocity Log switched off.

The OceanSurveyor 75 kHz recorded single pings, pinging every 1.6 seconds in broadband mode, except for a phase when we examined the interferences when the ping rate was set to 2 seconds. The range was typically between 500 and 600m.

The OceanSurveyor 38 kHz also recorded single pings, pinging every 2.6 seconds in narrowband mode, except for the interference examination phase when the ping rate was set to 3 seconds. The range was typically 1500m.

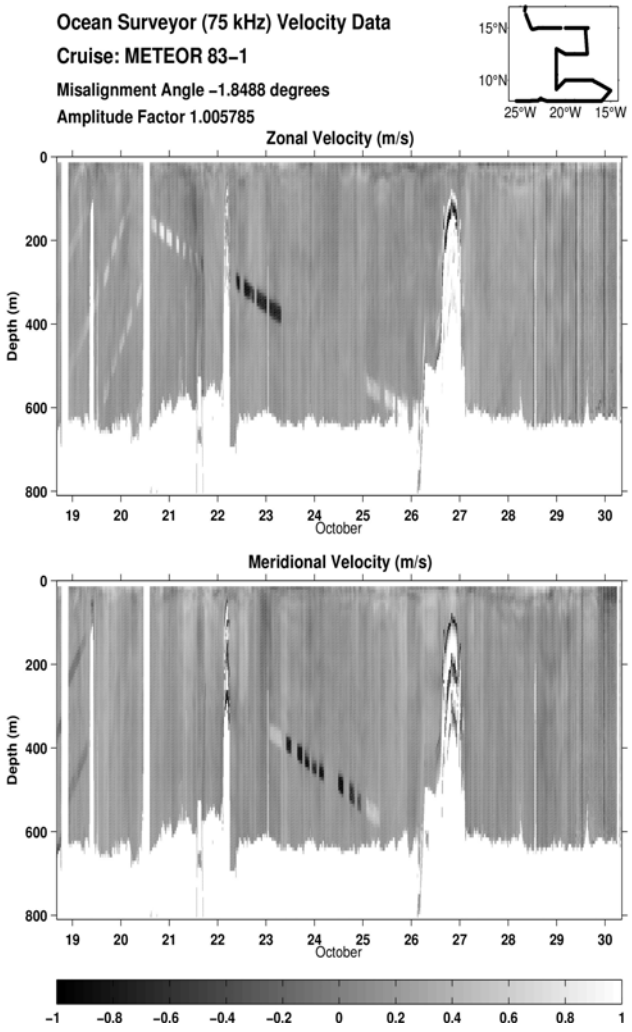

Fig. 5.8 Shipboard ADCP velocity data (75 kHz) versus time (UTC) for about the first third of the cruise. Interference from the 38 kHz system can be seen as diagonal stripes in the data until October 27 when the 38 kHz system was rotated by 45 degrees. Thereafter no interference occurred.

5.4.2 Lowered ADCP sampling

(Gerd Krahmann)

For five profiles (CTD #14 to #18) the CTD-System used was equipped with two Teldyne RDI WH 300 kHz ADCPs. They were mounted within the CTD-Rosette with especially manufactures frames protecting the instruments and giving free way for the acoustic beams. A battery pack was mounted between the downlooking master instrument (SN #6468) and the uplooking slave instrument (SN #839), both ADCPs were connected to it as it is the connection point for the data interface cable. Both instruments were run with the same setup of 25 bins with 10 m binsize and single-ping mode, time between pings was 0.9 seconds. The lADCP was only used for four deep profiles near continental shelf.

Data processing took place during the cruise with the IFM-GEOMAR LADCP processing software V10.7, which includes both shear and inversion methods to derive an absolute velocity

profile. As additional data necessary for the processing the corresponding pre processed CTD files for the cast P T S, time and navigation data were used.
Both RDI instruments performed well and resulted in good deep ocean velocity profiles.

5.5 Microstructure Measurements

5.5.1 Microstructure drop sonde

(Sabine Haase, Rudi Link)

General:
The focus of the microstructure measurement program was to advance understanding of mixing processes in the GUTRE (Guinea Upwelling region Tracer Release Experiment) region and to quantify spatial and temporal variability of diapycnal mixing in the OMZ. It combined the research objectives of the Junior Research Group (DFG Emmy Noether-Nachwuchsgruppe) "Microstructure" focussing on quantifying the impact of upper ocean diapycnal mixing processes on the variability of sea surface temperature and subproject A3 of Sonderforschungsbereich 754 aiming at quantifying diapycnal fluxes of oxygen in the oxygen minimum zone. The measurement program completed a data set consisting of microstructure profiles of shear and temperature, CTD profiles and ship-board velocity profiles that were previously collected during the tracer hunt cruises (M80/2 and MSM10/1) and the tracer release cruise (MSM08/1).

Sampling and technical aspects:
During M83/1, microstructure data was sampled on 23 stations, usually between CTD casts and GO-FLO stations. At each station 3 profiles of microstructure shear and temperature fluctuations were recorded from the surface to a depth of about 450 m. A total of 72 profiles were collected utilizing about 36 hours of ship time during the cruise.

The loosely-tethered microstructure profiling system (manufacturer: Sea and Sun Technology, Trappenkamp, Germany) used consisted of a profiler (MSS90-D II / SN 032), a winch and a data interface. The profiler was equipped with four shear sensors (airfoil type PNS06, SN 6003, SN 6029, SN 6044, SN 6045), a fast-responding temperature sensor (microthermistor FP07), a probe acceleration sensor (1 ms response) and tilt sensors. Additionally, mounted conductivity, temperature (Pt 100) and pressure sensors sampled at a lower frequency (24 Hz). A set-up of four shear sensors was chosen to allow for investigations of the strength of anisotropy of turbulence at dissipative scales that may occur in regions of strong stratification and/or in regions where weak turbulence levels prevail.

The profiler was optimized to sink at a rate of about 0.6 m/s. Shear fluctuations recorded due to vibration of the profiler while sinking are recorded by the acceleration sensor and can be removed from the shear data during post-processing. With this set up, the noise level for dissipation rates of turbulent kinetic energy is less than $6x10^{-10}$ W kg^{-1} and less than $1x10^{-11}$ C^2s^{-1} for temperature variance. All sensors were mounted to the measuring head of the profiler, with the exception of the internal pitch and roll sensors that are located inside the pressure housing. Shear sensor 2 (SN 6029) occasionally malfunctioned during some casts. However, it was decided not to replace the sensor as assessments of the strength of anisotropy could not have been made otherwise. During the later part of the cruise, the cable close to the profiler had to be

replaced due to a broken isolation and about 200 m of cable had to be removed due to cable damage.

Preliminary Results:

Previously collected data from this region had indicated high correlation of vertically-averaged turbulent eddy diffusivities (150m-450m) to elevated shear of horizontal velocity in the same depth range. Enhanced shear was predominately observed in regions of rough bathymetry, probably due to upward-propagating high baroclinic gravity waves that are generated due to interaction of tides with topography in the deeper ocean. The preliminary processed data from this cruise exhibits somewhat similar features. Elevated eddy diffusivities were found in the region around 8°N, 21°W, where several seamounts are located (Figure 5.9). In this region, the MicroRider/Glider was deployed and we expect to obtain a detailed description of the mixing processes at tropical seamounts from the first five days of the MicroRider/Glider dataset. Rather unexpectedly, elevated eddy diffusivities were also present at 10°N, 25°W and 11°N, 28°W, where no rough topography is indicated. Data from the previous cruises had indicated low mixing for this region. A detailed analysis of the combined microstructure/CTD/VMADCP dataset will be necessary to explain the elevated eddy diffusivities for this region.

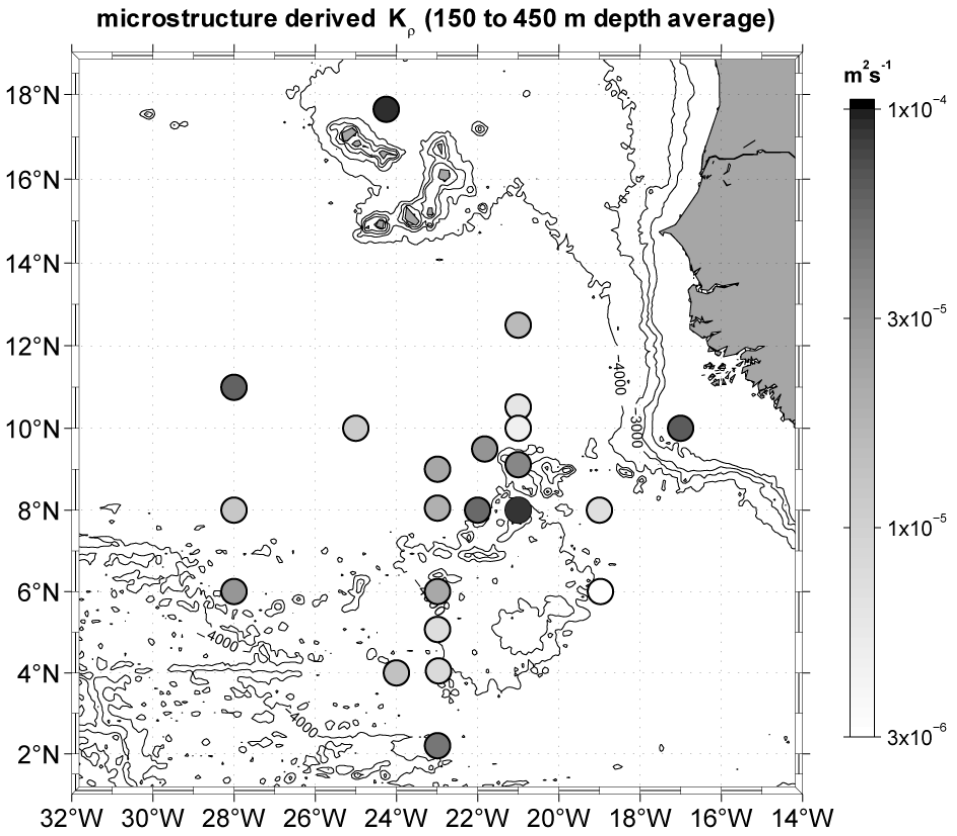

Fig. 5.9. Vertically-averaged (150 to 450 m) turbulent eddy diffusivities in the sampling area. Eddy diffusivities were calculated from the dissipation rates of turbulent kinetic energy (ε) determined from the microstructure shear data using $K_{rho}=\Gamma\varepsilon N^{-2}$, where $\Gamma=0.2$ represents mixing efficiency and N^2 stratification.

5.5.2 Microstructure Glider

(Gerd Krahmann)

During the cruise one glider was deployed and recovered 11 days later. This glider (system ifm02/deepy) was used in a configuration with a microrider microstructure sonde attached, similar to a setup on M80/1. The glider was deployed on October, 24, 2010 and recovered on November, 4, 2010. This represents a recovery about a week earlier than originally planned. After about 1 week the voltages transmitted in near realtime to the land station at IFM-GEOMAR indicated a sudden change. As the glider itself showed no hints of malfunction a problem with the self-contained microrider was supposed. We thus decided to deviate from the originally planned cruise track and recover the glider early. Upon recovery and inspection it was found that a forward compartment of the microrider contained a small amount of water. A bulkhead prevented damage to the microrider's main electronics, thus likely limiting the upcoming repair costs. Inspection of the microrider's data showed that data was indeed only collected until the change in voltages reported by the glider. The measurements amounted to about 40 microstructure profiles which should still be sufficient for an analysis of the ocean mixing rates in the deployment area.

5.6 Glider recovery

(Gerd Krahmann)

During the cruise another autonomous glider was recovered. In August 2010 system ifm11 had been deployed near Mindelo/Cape Verde and had since travelled 2100km along the 23W Meridian. This glider had worked without major problems for the whole 81 day long deployment. At the time of the recovery on October, 29, 2010 the batteries of this system were nearly drained marking the maximum possible deployment length of this particular setup. The recovery was performed using RV METEOR's zodiac. The glider had some limited growth of barnacles which had caused a slowdown of 25% during the last deployment weeks. Initial inspection of the data recovered from the glider as well as data already transmitted via satellite showed that all systems worked fine for the whole deployment.

5.7 Mesocosm experiments

(Helena Hauss, Jasmin Franz, Kerstin Nachtigall)

Pelagic Community Response to Changes in Nutrient Stoichiometry:
Macronutrient levels (Si, N, P) and their ratios determine the functional type, size structure, and species composition of the phytoplankton community as well as its elemental composition. This, in turn, may affect the nutritional value of phytoplankton for primary consumers and higher trophic levels as well as the efficiency of the biological pump.

Objectives
The aim during this cruise was to experimentally test the influence of inorganic N and P concentrations and their ratios on phytoplankton dynamics in on-board mesocosm trials. In addition, station work along transects, including sampling of CTD casts (see 5.2.3) and WP2 plankton nets (see 5.2.4), was conducted in order to describe the pool and biogeochemical fluxes of macronutrients as well as feeding and excretion characteristics of zooplankton.

Methods

One mesocosm growth trial was run during the cruise lasting for 11 days.

The mesocosms were filled with surface water from 5 m depth on the West African shelf (Station # 831; 15°0.01'N 17°30.01'W), using a peristaltic pump to minimize damage to plankton organisms. The experimental setup comprised twelve 150L mesocosm bags floating for cooling in four flow-through water baths which are gimbals-mounted to prevent spilling by the ship's movement. Temperatures within the mesocosms were generally less than 2°C higher than SST. Four different N:P target ratios (16, 8, 5.5 and 2.8) were adjusted by adding according concentrations of nitrate and phosphate. In all mesocosms, an equal amount of silicate (15 µmol l^{-1}) and a trace metal mix (Provasoli solution) was added in order to avoid any nutrient limitation effects caused by depleted silicate or trace metals. The phytoplankton response was monitored on a daily basis in terms of community structure, production, and distribution of dissolved and particulate carbon, nitrogen and phosphorus. Specifically, samples were taken for nutrient concentrations of N/P/Si (performed on board; method see 5.1.3), POC/PON/POP, DOC, DON/DOP (performed on board; method see 5.2.3), HPLC to determine phytoplankton pigments, BSi (biogenic silicate; indicator for the presence of diatoms in surface waters), fatty acid methyl ester analysis (FAME), flow cytometry for the assessment of nanoplankton and bacterial biomass and lugol-fixed samples for cell counts of microplankon. Samples for chlorophyll a were also taken and processed on board on the same day. As an indicator for phytoplankton biomass, chlorophyll a concentrations allowed us to keep track of the phytoplankton bloom development. Also on a daily basis, Carolin Löscher took samples for DNA-analysis and N_2O, and at termination of the experiment, for metagenomics. Furthermore, a ^{15}N-incubation to determine N-fixation was conducted on day 8 of the experiment by Carolin Löscher.

Helena Hauss carried out satellite experiments by incubating adult females of the copepod *Undinula vulgaris* caught during net hauls (see 5.2.4) with medium from the mesocosms during the primary and secondary bloom. After two days of incubation, individuals were sampled for RNA/DNA (as a proxy for nutritional condition).

At termination of the mesocosm trials, zooplankton >100µm was concentrated from 20L and fixed in a 4% formaldehyde in seawater solution to determine their abundance. The >200µm size fraction was sampled for stable isotopes of carbon and nitrogen.

After termination of the mesocosm incubation on the 01/11/2010, the mesocosm medium was transferred into 2L Nalgene bottles. 2.5 µmol l^{-1} phosphate and trace metals (Provasoli) were added, plus one control of each N:P treatment without any further addition. After incubation in the water baths for 5 days, the incubation was terminated and sampled for phytoplankton pigments, POC/PON and DNA. This additional experiment was run in order to potentially trigger the growth of nitrogen fixers (e.g. *Trichodesmium*), which happened to form an extensive bloom on station #831, where the mesocosms were filled initially, but were outcompeted after the nutrient addition by diatoms.

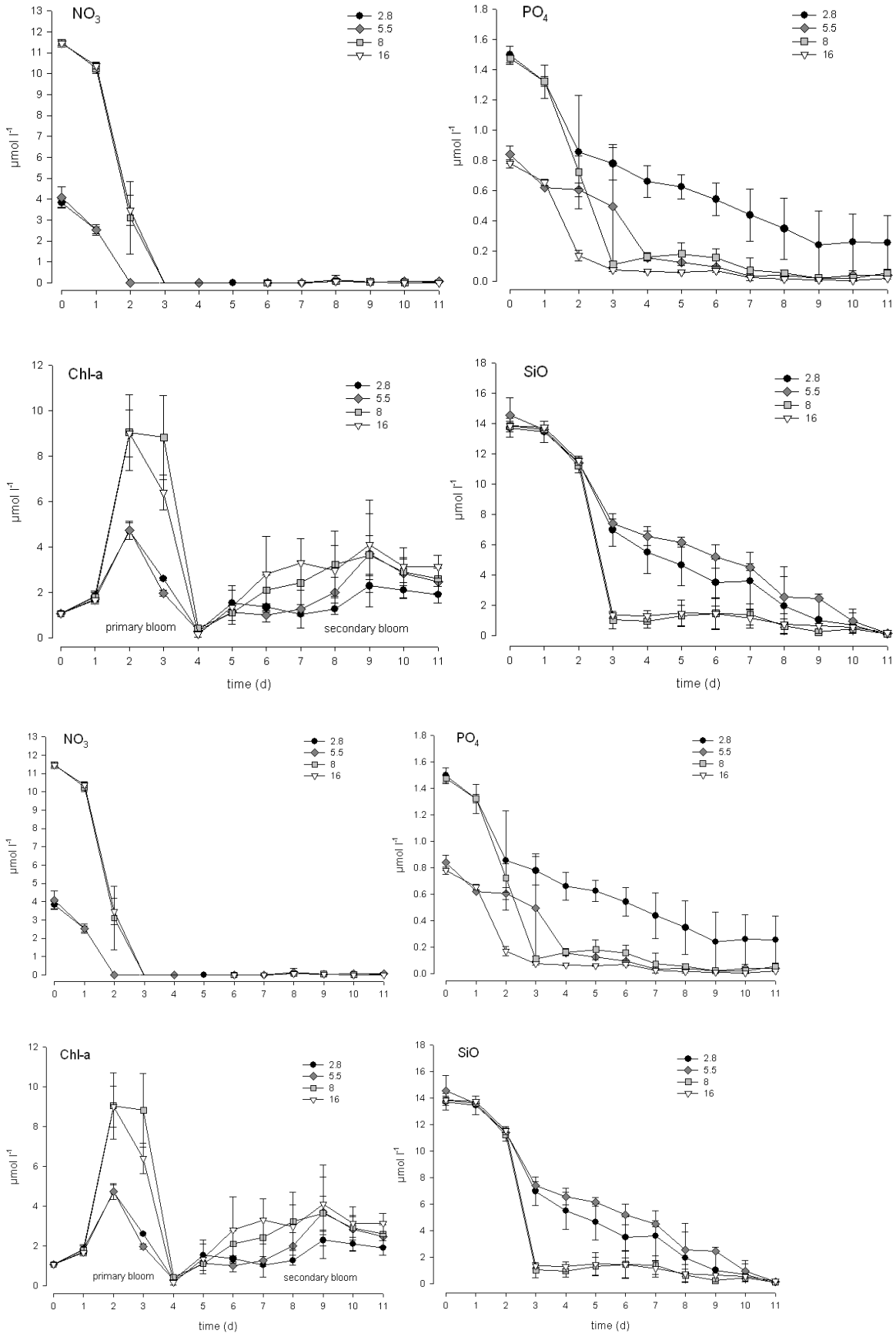

Fig. 5.10 Mesocosm experiment: Dissolved inorganic nutrient (Nitrate, Phosphate, Silicate) uptake and Chlorophyll-a development over time at four N:P treatment levels (2.8, black circles, 5.5, dark grey

diamonds, 8, light grey squares, and 16, white triangles). Values are treatment means (*n*=3), error bars denote standard deviation.

Results (Shipboard)

The initial fertilization resulted in an immediate increase in Chl-a (i.e. phytoplankton biomass). Already on day 2, the treatments clearly separated (Figure 5.10). High initial nitrate addition resulted in about twice the Chl-a level. No difference among N:P ratios was detected, i.e. the phosphate level did not control biomass development. This primary bloom lasted only until day 3, it was apparently rapidly grazed. Simultaneously, the silicate concentration showed a rapid decline in the two "high N" treatments, indicating that diatoms were a functional group that benefitted from the nitrate addition. In the lowest N:P treatment, phosphate was not taken up completely until the termination of the experiment. Dissolved organic nitrogen (DON) accumulated especially in the "high N" treatments, while dissolved organic phosphorus (DOP) fluctuated strongly and did hardly accumulate in all treatments (Figure 5.11).

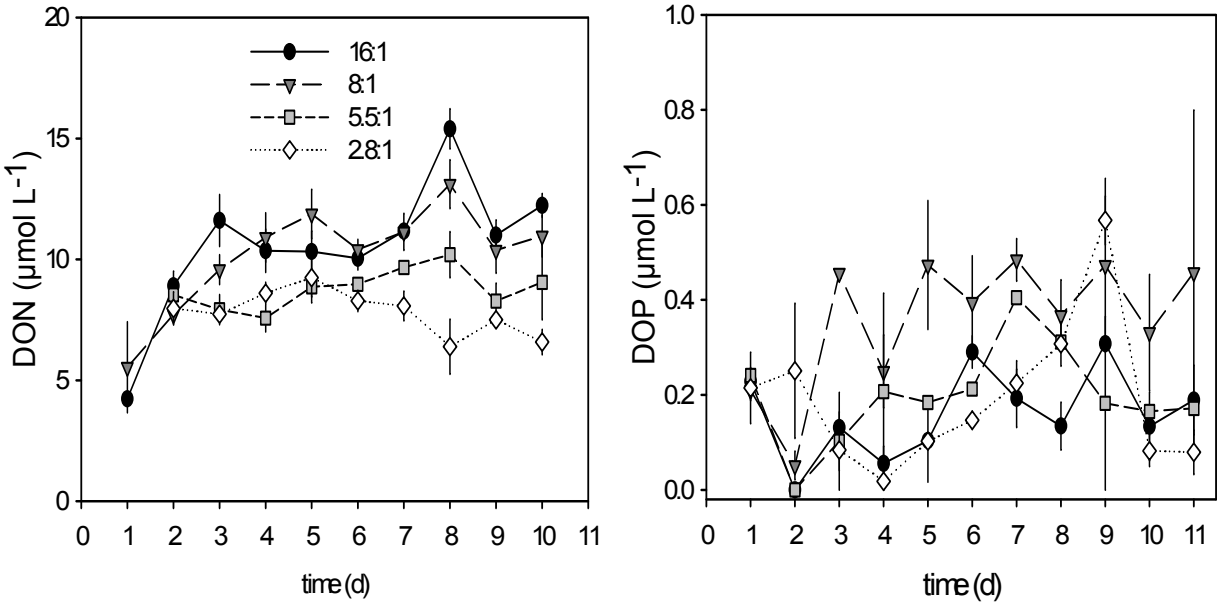

Fig. 5.11 Mesocosm experiment: Dissolved organic nitrogen (DON) and phosphorus (DOP) over time at four N:P treatment levels (2.8, black circles, 5.5, dark grey diamonds, 8, light grey squares, and 16, white triangles). Values are treatment means (*n*=3), error bars denote standard deviation.

5.8 Calibration of Aanderaa oxygen optodes

(Gerd Krahmann, Janin Schaffer, Karen Stange)

During this cruise a number of Aanderaa oxygen sensing optodes were run through several calibration steps. They encompassed a 0%-100% test, a 1200m CTD profile, a second 0%-100% test, replacement of the optode foils and subsequent 0%-100% calibration, a second 1200m CTD profile, and a third 0%-100% test. All data was logged with optode loggers developed in our

group. The resulting data will be analyzed at home and should result in better calibration of the optodes, some of which were previously used on autonomous glider systems or in moorings.

Serial Number	Calibration Dates	Type	Comments
1059	20.10.10 – 10.11.10	5013 / glider	used in glider deepy
1184	4.11.10 – 10.11.10	3830 / glider	
1188	8.11.10 – 9.11.10	3830 / glider	used in glider ifm11
1067	7.11.10 – 7.11.10	3830 / normal	
1187	7.11.10 - 7.11.10	3830 / glider	
1069	4.11.10 – 7.11.10	3830 / normal	
1068	3.11.10 – 3.11.10	3830 / normal	defect
1072	2.11.10 – 2.11.10	3830 / normal	
1183	1.11.10 – 3.11.10	3830 / glider	
1186	5.11.10 – 7.11.10	3830 / glider	
1207	3.11.10 – 3.11.10	5013 / glider	

5.9 Underway measurements

(Stephanie Gleixner)

The meteorological data recorded on the M83/1-cruise (here data from 18.10.2010 to 12.11.2010 is shown) includes global radiation, wind speed and direction, air temperature, relative humidity, duration of precipitation, air pressure and dew point. In addition sea surface temperatures and sea surface salinity have been recorded by thermometers in 2 meter depth and a thermosalinograph. After the 6th November, also longwave downwelling radiation was available. All data is preliminary and not certified by DWD.

To avoid an overestimation of air temperatures due to strong insolation, the minimum of port and starboard temperatures was used. In contrast the wind speed maximum was chosen, to minimize the impact of the shielding effect of the ship on the data set. For the other data, the average of starboard and port was used.

The sea surface temperature and salinity was compared to CTD data at 3 meter depth. That shows mean differences of 0.059 PSU for salinity (lower values in CTD data) and 0.07 °C for temperature (higher values in CTD data) (Figure 5.12). The corrected data sets were used to derive the sensible and latent heat flux by bulk formulas (Figure 5.13).

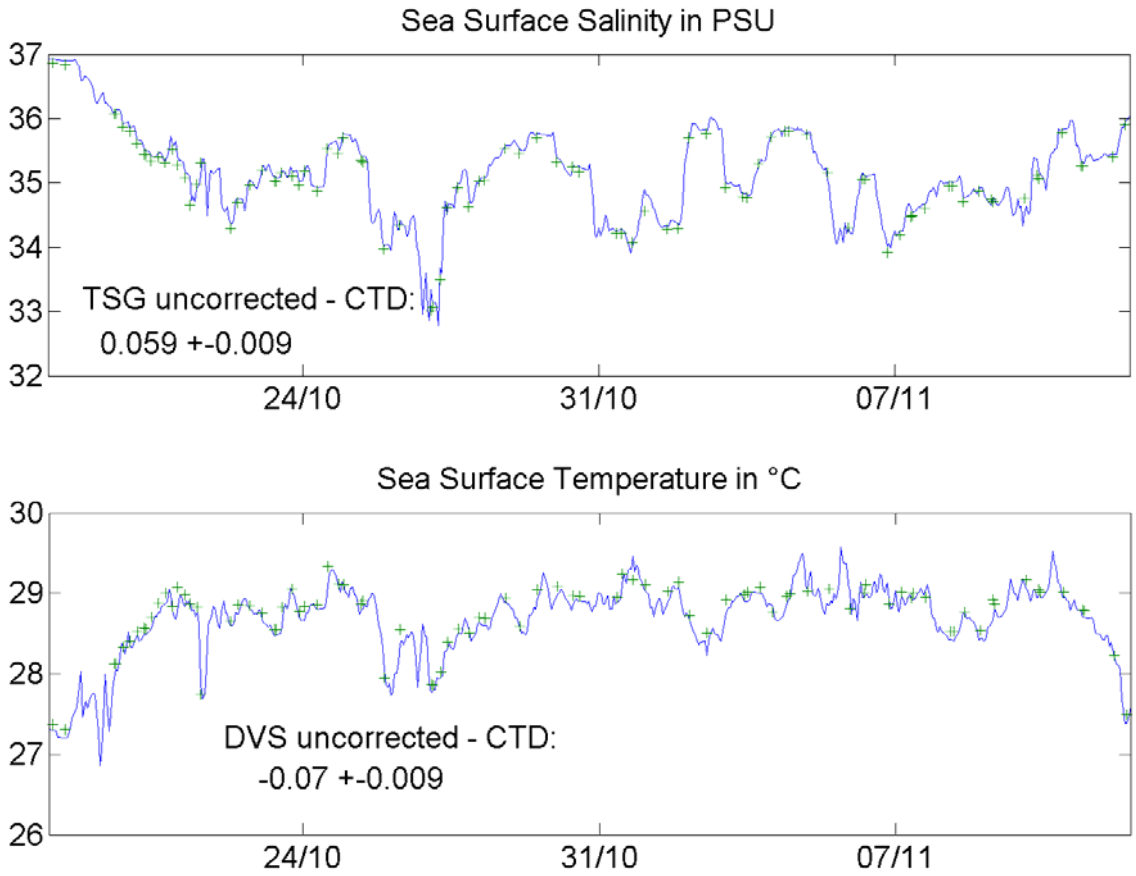

Fig. 5.12 Uncorrected sea surface salinity in PSU and sea surface temperature in °C recorded during M83/1 (lines) in comparison to CTD measurements (crosses).

To gain a complete data set for the heat fluxes, the outgoing longwave radiation was calculated according to Pickard and Emery (Descriptive Physical Oceanography, Pergamon Press, 1990). The necessary information about cloud cover was estimated from the difference between incoming global radiation and TAO solar radiation. For the time period of 6.11.-12.11.2010 outgoing longwave radiation was also calculated from the measured downwelling radiation. Comparing these data sets shows that the estimation of cloud cover leads to an overestimated diurnal cycle in the calculated longwave radiation, but on average there is a good agreement.

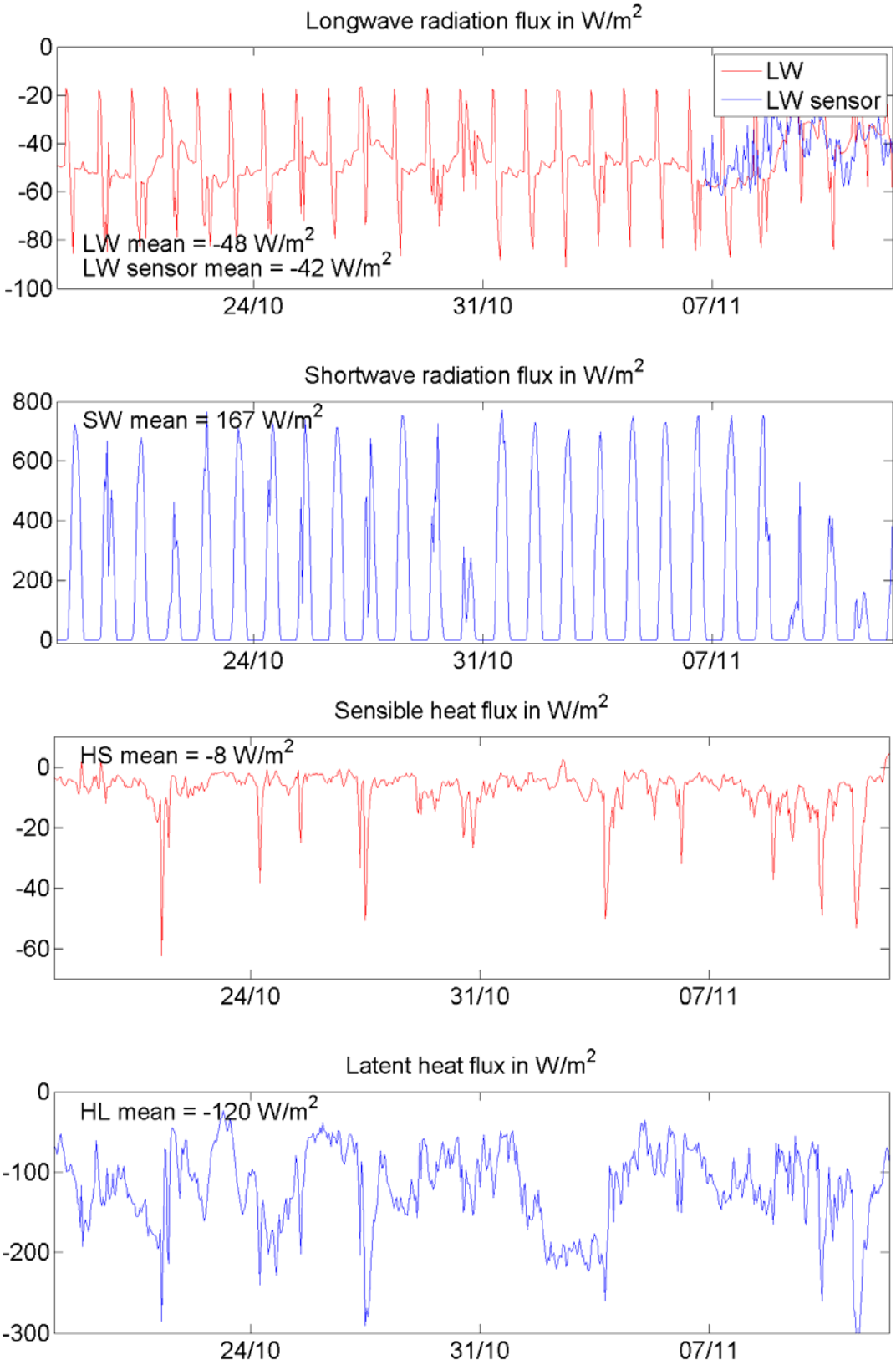

Fig. 5.13 Shortwave radiation, longwave radiation, sensible heat flux and latent heat flux in W/m^2

6 Ship's Meteorological Station

(Andreas Raeke)

On the morning October the 14Th 2010 research vessel Meteor left the port of Las Palmas on expedition M83/1 towards the Cape Verde Islands.

The main interest of this voyage was to study the variability of the oxygen minimum zones, the water mass properties, the distribution of oxygen and nutrients and the determination of water mass transports in the northeastern tropical Atlantic.

The journey of the Meteor began with a partly cloudy sky ahead of a low pressure system west of Madeira. The air temperature was hovering around 23 degree Celsius and the westerly wind showed forces from 3 to 4 BFT.

On the day before in the harbour area 4 Funnel clouds were observed, reaching the surface of the water. The Madeira low pressure trough brought no weather to the cruise to the Cap Verde Island. Low pressure gradients dominated the weather pattern until the 19Th. Partly cloudy conditions were experienced with NE'ly trade winds with force 3 to 4 BFT and a swell /sea from 1 to 1.5 m.

By approaching the Cape Verde Islands the humidity in the lower level of the atmosphere increased. During the afternoon of the 19Th light showers were experienced. During the passage through the Cape Verde islands the local wind pattern were studied.

On the 18th west of Sao Nicolau close to sunset the wind increased to force 6 and shifted from northeast to north. However in the lee of the island weak southwesterly winds were experienced. On the 19th southwest of the island Santiago similar pattern were noticed with a decrease of wind within the lee of the island.

Until the 22Th the cruise to Senegal was influenced by humid air, isolated showers and thunderstorms developed and gusts of strength 8 BFT were experienced. The NE 'ly trade winds decreased to wind forces 1 to 2 BFT, later turning to the southeast. The swell/sea was about 1m. Further south until the 24TH low air pressure differences were experienced. Mainly fine weather conditions dominated the cruise with northerly winds of force 4 BFT and swell/sea of 1 to 1.5 m.

Along the 10TH latitude Meteor experienced repeated showers and thunderstorms with gusts up to 8 BFT. Apart from thundery showers only northerly wind about 2 BFT were measured. The swell /sea reached 1 to 1.5 m, within showers /thunderstorms a height of 2 m was measured.

On the 25Th a tropical wave was located at 23W 8N. Later on hurricane Tomas developed which had no impact on the cruising area of the Meteor.

On the 27TH about 8 north the humidity in the atmosphere increased again. From the 29TH strong convective clouds produced local showers and thunderstorms with squalls. Apart from thundery showers only wind forces about 3 BFT from various directions were experienced. From November the 1TH until the 3th on the way north (9 and 11N)the NE'ly trade winds set in with a mainly constant force of 4 BFT. Swell / sea was 1.5 to 2m. On the 03.11. isolated showers and thunderstorms occurred.

The next two days the wind shifted southeast with forces 2 to 3 BFT with only isolated showers. On the 6Th of November only weak east to northeastwinds were measured. The next following days the wind increased to a constant BFT 4.

From the 8Th to 11Th Meteor on its way north from 2°N 23°W humid air penetrated the cruising area resulting in scattered showers and thunderstorms. The swell/sea was still no higher than 1 to 1.5 m. The next following day Meteor was outside the ITC and the shower activity

decreased. A constant and steady trade wind of 4 to 5 Bft was experienced. The swell / sea rose up to 2m.

On the morning of the 13 Th the voyage ended in the port of Mindelo.

7 Station List M83/1

	P#	Stat.	Date	Time	Latitude	Longitude	max. p [db]	Comment
GO-FLO	001	M769	17/10/10	23:15	17° 39.01' N	24° 15.01' W	80	Nutrients, Trace Metals (10,20,40)
MSS	001	M770	18/10/10	00:03	17° 39.04' N	24° 14.99' W	484	
MSS	002	M770	18/10/10	00:33	17° 39.45' N	24° 14.68' W	440	
GO-FLO	002	M771	18/10/10	01:33	17° 39.03' N	24° 14.97' W	190	Nutrients, Trace Metals (10, 150, 170)
T-CTD	002	M772	18/10/10	02:31	17° 39.03' N	24° 14.96' W	3639	Tracer, O2, H2O2/Fe(II), Mn, CDOM, Nutrients, DOM, DNA, Salinity
Plancton net	001	M773	18/10/10	05:20	17° 38.98' N	24° 14.97' W	50	
PIES		M774	18/10/10	06:18	17° 35.67' N	24° 14.47' W		
GO-FLO	003	M775	18/10/10	08:47	17° 38.98' N	24° 14.96' W	100	Nutrients, Trace Metals (10)
Bio-CTD	003	M776	18/10/10	09:11	17° 38.96' N	24° 15.03' W	400	O2, H2O2/Fe(II), Mn, CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation,N2O, Mn/CDOM, Salinity
GO-FLO	004	M777	18/10/10	09:58	17° 38.93' N	24° 15.10' W	700	Nutrients, Trace Metals (450)
Multibeam		M778	18/10/10	18:24	16° 37.89' N	24° 28.90' W		
Bio-CTD	004	M779	19/10/10	13:21	14° 59.97' N	22° 59.99' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation, CDOM, H2O2, Fe(II)
Plancton net	002	M780	19/10/10	13:50	15° 0.19' N	23° 0.29' W	100	
T-CTD	005	M781	19/10/10	14:25	15° 0.43' N	23° 0.48' W	1200	Tracer, O2, H2O2/Fe(II), CDOM, Nutrients, CDOM, DNA, Salinity
T-CTD	006	M782	19/10/10	18:16	15° 0.13' N	22° 29.96' W	1200	Tracer, O2, H2O2/Fe(II), Nutrients, CDOM, DNA, Salinity
T-CTD	007	M783	19/10/10	22:07	15° 0.11' N	22° 0.06' W	1200	Tracer, Nutrients, CDOM, DNA, Salinity, HPLC/POM
T-CTD	008	M784	19/10/10	01:58	14° 59.84' N	21° 30.09' W	1200	Tracer, Nutrients, CDOM, DNA, Salinity
Bio-CTD	009	M785	20/10/10	05:34	14° 59.96' N	20° 59.97' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
Plancton net	003	M786	20/10/10	06:06	14° 59.94' N	20° 59.96' W	50	
T-CTD	010	M787	20/10/10	06:46	14° 59.98' N	20° 59.92' W	1200	Tracer, O2, Nutrients, CDOM, DNA, Salinity
T-CTD	011	M788	20/10/10	10:19	15° 0.11' N	20° 29.94' W	1200	Tracer, O2, H2O2/Fe(II), CDOM, Nutrients, Salinity
T-CTD	012	M789	20/10/10	14:08	15° 0.02' N	20° 0.09' W	1200	Tracer, O2, H2O2/Fe(II), Nutrients, Salinity
T-CTD	013	M790	20/10/10	17:50	15° 0.05' N	19° 30.04' W	1200	Tracer, Nutrients, Salinity
T-CTD	014	M791	20/10/10	21:31	14° 59.96' N	19° 0.02' W	1200	Tracer, Nutrients, DNA, Salinity
T-CTD bottom	015	M792	21/10/10	01:20	14° 59.88' N	18° 30.11' W	2955	Tracer, Nutrients, Salinity
T-CTD bottom	016	M793	21/10/10	04:54	14° 59.99' N	18° 15.01' W	2615	no sample
T-CTD bottom	017	M794	21/10/10	08:17	15° 0.11' N	18° 0.05' W	2039	Tracer, O2, H2O2/Fe(II), Mn, CDOM, Nutrients, Salinity
T-CTD bottom	018	M795	21/10/10	11:37	15° 0.01' N	17° 45.01' W	1195	Salinity
GO-FLO	005	M796	21/10/10	14:06	15° 0.01' N	17° 30.04' W	50	Nutrients, Trace Metals
Bio-CTD	019	M797	21/10/10	14:35	15° 0.01' N	17° 30.01' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation,Salinity
Mesokosmen		M797	21/10/10	15:00	15° 0.01' N	17° 30.01' W		12 Mesokosmen were filled with surface water
GO-FLO	006	M798	22/10/10	06:18	12° 30.06' N	17° 37.36' W	70	Nutrients, Trace Metals (10, 30, 50)
Plancton net	004	M799	22/10/10	06:56	12° 30.07' N	17° 37.33' W	50	

	P#	Stat.	Date	Time	Latitude	Longitude	max. p [db]	Comment
Bio-CTD	020	M800	22/10/10	07:04	12° 30.07' N	17° 37.33' W	400	O2, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation,Salinity
GO-FLO	007	M801	22/10/10	07:47	12° 30.07' N	17° 37.33' W	310	Nutrients, Trace Metals (10, 110, 210)
T-CTD	021	M802	22/10/10	10:58	12° 29.99' N	17° 59.99' W	1202	Tracer, O2, H2O2/Fe(II), CDOM, Salinity
T-CTD	022	M803	22/10/10	18:16	12° 29.98' N	18° 59.98' W	1200	Tracer, O2, Nutrients, Salinity
T-CTD	023	M804	23/10/10	00:33	12° 29.98' N	19° 59.67' W	1200	Tracer, Salinity, Chl-a
Plancton net	005	M805	23/10/10	07:34	12° 59.96' N	20° 59.89' W	50	
Bio-CTD	024	M806	23/10/10	07:44	12° 59.94' N	20° 59.85' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
T-CTD	025	M807	23/10/10	08:50	12° 59.94' N	20° 59.85' W	1201	Tracer, O2, Salinity
T-CTD	026	M808	23/10/10	12:31	12° 29.94' N	20° 59.98' W	1200	Tracer, O2, H2O2/Fe(II), CDOM, Salinity
MSS	003	M809	23/10/10	13:49	12° 30.15' N	21° 0.12' W	480	
MSS	004	M809	23/10/10	14:17	12° 30.58' N	21° 0.30' W	476	
MSS	005	M809	23/10/10	14:47	12° 30.98' N	21° 0.55' W	460	
T-CTD	027	M810	23/10/10	18:02	11° 59.90' N	21° 0.00' W	1200	Tracer, H2O2/Fe(II), CDOM, DNA, Nutrients
T-CTD	028	M811	23/10/10	21:32	11° 29.99' N	21° 0.04' W	1200	Tracer, Salinity
T-CTD	029	M812	24/10/10	01:11	11° 0.05' N	20° 59.86' W	1200	Tracer, Salinity
T-CTD	030	M813	24/10/10	04:45	10° 29.97' N	21° 0.00' W	1200	Tracer, Salinity
MSS	006	M814	24/10/10	05:49	10° 30.07' N	20° 59.94' W	411	
MSS	007	M814	24/10/10	06:32	10° 30.62' N	20° 59.47' W	421	
MSS	008	M814	24/10/10	07:00	10° 30.92' N	20° 59.22' W	468	
Plancton net	006	M815	24/10/10	07:23	10° 31.10' N	20° 59.07' W	100	
Bio-CTD	031	M816	24/10/10	07:33	10° 31.13' N	20° 59.10' W	400	H2O2/Fe(II), Mn, CDOM, DOM, Chl-a, POM, DNA, N2-fixation
MSS	009	M817	24/10/10	08:12	10° 31.22' N	20° 59.07' W	502	
MSS	010	M817	24/10/10	08:12	10° 31.22' N	20° 59.07' W	475	
MSS	011	M817	24/10/10	08:12	10° 31.22' N	20° 59.07' W	427	
GLIDER		M818	24/10/10	09:39	10° 31.86' N	20° 58.61' W		
T-CTD	032	M819	24/10/10	14:24	9° 59.88' N	21° 0.00' W	1200	Tracer, O2, H2O2/Fe(II), CDOM, Salinity
MSS	012	M820	24/10/10	15:31	9° 59.94' N	21° 0.05' W	515	
MSS	013	M820	24/10/10	15:45	10° 0.11' N	20° 59.88' W	458	
MSS	014	M820	24/10/10	16:49	10° 1.03' N	20° 59.47' W	445	
T-CTD	033	M821	24/10/10	20:03	9° 30.00' N	21° 0.02' W	1200	Tracer, Nutrients, DNA, POM/DOC, Salinity
T-CTD	034	M822	24/10/10	23:13	9° 7.03' N	20° 59.97' W	1201	Tracer, Salinity
MSS	015	M823	25/10/10	00:17	9° 7.12' N	20° 59.91' W	526	
MSS	016	M823	25/10/10	00:45	9° 7.30' N	20° 59.47' W	434	
MSS	017	M823	25/10/10	01:10	9° 7.44' N	20° 59.10' W	436	
Plancton net	007	M824	25/10/10	08:29	9° 59.98' N	19° 59.94' W	100	
Bio-CTD	035	M825	25/10/10	08:45	10° 0.03' N	19° 59.86' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
T-CTD	036	M826	25/10/10	09:44	10° 0.10' N	19° 59.76' W	1205	Tracer, O2, H2O2/Fe(II), CDOM, Salinity
T-CTD	037	M827	25/10/10	16:02	10° 0.03' N	18° 59.99' W	1200	Tracer, O2, H2O2/Fe(II), CDOM, Nutrients, DNA, POM/DOC, Salinity
T-CTD bottom	038	M828	25/10/10	22:23	9° 59.99' N	17° 59.99' W	3125	Tracer, Salinity
T-CTD bottom	039	M829	26/10/10	03:31	9° 59.85' N	17° 29.80' W	732	Tracer, Nutrients, Salinity Standard (niskin 1-3)
Plancton net	008	M830	26/10/10	06:48	10° 0.01' N	16° 59.96' W	50	
GO-FLO	008	M831	26/10/10	07:00	9° 59.99' N	16° 59.98' W	90	Nutrients, Trace Metals (10, 30, 50)
Bio-CTD	040	M832	26/10/10	07:28	9° 59.97' N	16° 59.98' W	400	O2, H2O2/Fe(II), Mn, CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
GO-FLO	009	M833	26/10/10	08:17	9° 59.95' N	16° 59.99' W	310	Nutrients, Trace Metals (10, 110, 210)

	P#	Stat.	Date	Time	Latitude	Longitude	max. p [db]	Comment
T-CTD bottom	041	M834	26/10/10	09:23	10° 0.00' N	17° 0.16' W		Error, new profile after MSS
MSS	018	M835	26/10/10	09:53	10° 0.02' N	17° 0.34' W	415	
MSS	019	M835	26/10/10	10:17	10° 0.01' N	17° 0.69' W	407	
MSS	020	M835	26/10/10	10:42	10° 0.01' N	17° 1.09' W	434	
T-CTD bottom	041	M836	26/10/10	11:21	10° 0.01' N	17° 1.55' W	463	Tracer, O2, H2O2/Fe(II), Mn, CDOM
Bio-CTD	042	M837	27/10/10	00:52	8° 57.67' N	15° 2.64' W	400	Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
Plancton net	009	M838	27/10/10	01:24	8° 57.65' N	15° 2.64' W	50	
T-CTD bottom	043	M839	27/10/10	01:51	8° 57.66' N	15° 2.63' W	424	Tracer, O2, Salinity
T-CTD	044	M840	27/10/10	05:45	8° 30.01' N	15° 30.02' W	1200	Tracer, O2, Nutrients, Salinity
T-CTD	045	M841	27/10/10	10:21	7° 59.95' N	16° 0.03' W	1200	Tracer, H2O2/Fe(II), Nutrients, Salinity
T-CTD	046	M842	27/10/10	16:20	8° 0.00' N	17° 0.07' W	1200	Tracer, H2O2/Fe(II), Mn, CDOM, Nutrients, DNA, POC/DOC, Salinity
T-CTD	047	M843	27/10/10	22:24	8° 0.03' N	18° 0.07' W	1200	Tracer, Nutrients, Salinity
T-CTD	048	M844	28/10/10	04:20	8° 0.02' N	18° 59.99' W	1200	Tracer, Nutrients, Salinity
MSS	021	M845	28/10/10	05:24	8° 0.07' N	18° 59.95' W	542	
MSS	022	M845	28/10/10	06:11	8° 0.45' N	18° 59.28' W	502	
MSS	023	M845	28/10/10	06:40	8° 0.68' N	18° 58.88' W	485	
Plancton net	010	M846	28/10/10	07:00	8° 0.82' N	18° 58.65' W	50	
Bio-CTD	049	M847	28/10/10	07:08	8° 0.88' N	18° 58.68' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
T-CTD	050	M848	28/10/10	12:50	8° 0.11' N	20° 0.01' W	1200	Tracer, O2, H2O2/Fe(II), Mn, CDOM, Nutrients
T-CTD	051	M849	28/10/10	18:56	8° 0.03' N	20° 59.99' W	1200	Tracer, DOC/PO, DANN, Chl-a, Salinity
MSS	024	M850	28/10/10	20:11	8° 0.11' N	20° 59.95' W	543	
MSS	025	M850	28/10/10	20:39	7° 59.74' N	20° 59.93' W	547	
MSS	026	M850	28/10/10	21:05	7° 59.53' N	20° 59.86' W	556	
T-CTD	052	M851	29/10/10	02:56	8° 0.28' N	22° 0.22' W	1200	Tracer, Nutrients, Salinity
MSS	027	M852	29/10/10	04:02	8° 0.42' N	22° 0.09' W	456	
MSS	028	M852	29/10/10	04:47	8° 0.06' N	21° 59.52' W	519	
MSS	029	M852	29/10/10	05:36	7° 59.66' N	21° 58.81' W	437	
Plancton net	011	M853	29/10/10	09:55	8° 14.84' N	22° 42.90' W	100	
GLIDER		M854	29/10/10	10:07	8° 14.93' N	22° 42.86' W		
Bio-CTD	053	M855	29/10/10	10:16	8° 14.97' N	22° 42.82' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
T-CTD bottom	054	M856	29/10/10	12:50	8° 3.14' N	22° 59.86' W	4545	Tracer, O2, H2O2/Fe(II), Mn, CDOM, Nutrients, Salinity
MSS	030	M857	29/10/10	16:56	8° 3.08' N	22° 59.80' W	475	
MSS	031	M857	29/10/10	17:39	8° 2.60' N	23° 0.28' W	468	
MSS	032	M857	29/10/10	18:24	8° 2.02' N	23° 0.76' W	500	
T-CTD	055	M858	29/10/10	19:52	8° 2.16' N	23° 16.80' W	1200	Tracer, Nutrients, DOM, DANN, Salinity
Plancton net	012	M859	30/10/10	08:50	8° 0.01' N	25° 29.92' W	100	
Bio-CTD	056	M860	30/10/10	09:02	7° 59.98' N	25° 29.93' W	400	O2, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
GO-FLO	010	M861	30/10/10	09:48	7° 59.96' N	25° 29.98' W	70	Nutrients, Trace Metals (10, 30, 50)
GO-FLO	011	M862	30/10/10	11:30	7° 59.85' N	25° 29.99' W	310	Nutrients, Trace Metals (10, 110, 210)
T-CTD bottom	057	M863	30/10/10	13:02	7° 59.95' N	25° 29.99' W	3590	Tracer, O2, H2O2/Fe(II), Mn, CDOM, Nutrients, Salinity
Bio-CTD	058	M864	31/10/10	10:12	6° 0.03' N	27° 59.90' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
Plancton net	013	M865	31/10/10	10:44	6° 0.04' N	27° 59.72' W	100	
MSS	033	M866	31/10/10	11:05	5° 59.99' N	27° 59.60' W	556	
MSS	034	M866	31/10/10	11:32	5° 59.75' N	27° 59.52' W	550	
MSS	035	M866	31/10/10	12:02	5° 59.47' N	27° 59.36' W	545	

	P#	Stat.	Date	Time	Latitude	Longitude	max. p [db]	Comment
T-CTD	059	M867	31/10/10	12:38	5° 59.21' N	27° 59.15' W	1200	Tracer, O2, H2O2/Fe(II), Nutrients, Salinity
T-CTD	060	M868	31/10/10	19:16	6° 59.99' N	28° 0.00' W	1200	Tracer, Nutrients, POM, DOM, DNA, Salinity
T-CTD	061	M869	01/11/10	01:52	8° 0.02' N	28° 0.06' W	1200	Tracer, Nutrients, Salinity
MSS	036	M870	01/11/10	02:58	8° 0.08' N	28° 0.03' W	344	
MSS	037	M870	01/11/10	03:21	8° 0.11' N	27° 59.71' W	458	
MSS	038	M870	01/11/10	03:51	8° 0.07' N	27° 59.27' W	482	
MSS	039	M870	01/11/10	04:20	8° 0.05' N	27° 58.86' W	477	
MSS	040	M870	01/11/10	05:06	8° 0.04' N	27° 58.16' W	463	
MSS	041	M870	01/11/10	05:56	7° 59.97' N	27° 57.58' W	480	
Plancton net	014	M871	01/11/10	11:33	9° 0.09' N	28° 0.08' W	100	
GO-FLO	012	M872	01/11/10	12:01	9° 0.19' N	28° 0.13' W	400	Nutrients, Sampling for calibrations with filtered seawater (355, 370, 385)
T-CTD bottom	062	M873	01/11/10	14:46	9° 0.11' N	28° 0.06' W	5290	Tracer, O2, Nutrients, Salinity
Mesokosmen		M874	01/11/10	20:00	9° 0.01' N	27° 59.99' W		Mesokosmen experiment stopped
Bio-CTD	063	M874	01/11/10	20:43	9° 0.01' N	27° 59.99' W	400	Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
T-CTD	064	M875	02/11/10	02:44	9° 59.97' N	27° 59.96' W	1200	Tracer, Nutrients, Salinity
Bio-CTD	065	M876	02/11/10	09:48	11° 0.04' N	28° 0.06' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
Plancton net	015	M877	02/11/10	10:21	11° 0.09' N	28° 0.21' W	100	
MSS	042	M878	02/11/10	10:49	11° 0.19' N	28° 0.18' W	534	
MSS	043	M878	02/11/10	11:30	11° 0.33' N	27° 59.82' W	519	
MSS	044	M878	02/11/10	12:07	11° 0.50' N	27° 59.49' W	489	
T-CTD	066	M879	02/11/10	12:15	11° 0.50' N	27° 59.49' W	1200	Tracer, O2, H2O2/Fe(II), CDOM, Salinity
T-CTD	067	M880	03/11/10	00:17	10° 0.08' N	26° 29.91' W	1200	Tracer, Salinity
GO-FLO	013	M881	03/11/10	09:13	10° 0.06' N	24° 59.99' W	70	Nutrients, Trace Metals (10, 30, 50)
Bio-CTD	068	M882	03/11/10	09:37	10° 0.03' N	24° 59.98' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
Plancton net	016	M883	03/11/10	10:09	10° 0.04' N	24° 59.99' W	100	
GO-FLO	014	M884	03/11/10	10:42	10° 0.45' N	24° 59.88' W	310	Nutrients, Trace Metals (10, 110, 210)
T-CTD	069	M885	03/11/10	11:40	10° 0.46' N	24° 59.85' W	1200	Tracer, O2, H2O2/Fe(II), Salinity
MSS	045	M886	03/11/10	12:44	10° 0.52' N	24° 59.92' W	426	
MSS	046	M886	03/11/10	13:12	10° 0.91' N	24° 59.86' W	486	
MSS	047	M886	03/11/10	13:37	10° 1.16' N	24° 59.69' W	477	
T-CTD	070	M887	03/11/10	19:30	10° 0.02' N	24° 0.00' W	1200	Tracer, POC/DOM, DNA, Salinity
T-CTD	071	M888	04/11/10	02:25	9° 59.94' N	22° 59.98' W	1200	Tracer, Nutrients, Salinity
GLIDER		M889	04/11/10	10:18	9° 30.09' N	21° 50.75' W		
Bio-CTD	072	M890	04/11/10	10:30	9° 30.06' N	21° 50.84' W	400	O2, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
Plancton net	017	M891	04/11/10	11:03	9° 30.06' N	21° 50.83' W	100	
T-CTD	073	M892	04/11/10	11:35	9° 30.09' N	21° 50.81' W	1200	Tracer, O2, Salinity
MSS	048	M893	04/11/10	12:42	9° 30.04' N	21° 50.76' W	490	
MSS	049	M893	04/11/10	13:07	9° 29.82' N	21° 50.38' W	487	
MSS	050	M893	04/11/10	13:32	9° 29.64' N	21° 50.01' W	476	
T-CTD	074	M894	04/11/10	22:24	8° 26.96' N	20° 59.39' W	1200	Tracer, Salinity
T-CTD	075	M895	05/11/10	04:32	7° 30.09' N	20° 59.99' W	1200	Tracer, Salinity
Plancton net	018	M896	05/11/10	05:33	7° 30.00' N	21° 0.03' W	50	
Bio-CTD	076	M897	05/11/10	06:14	7° 30.00' N	20° 59.99' W	400	O2, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
T-CTD	077	M898	05/11/10	09:35	7° 0.05' N	20° 59.98' W	1200	Tracer, Salinity
T-CTD	078	M899	05/11/10	16:10	6° 0.01' N	21° 0.01' W	1200	Tracer, Nutrients, DOM/POC, DNA, Salinity

	P#	Stat.	Date	Time	Latitude	Longitude	max. p [db]	Comment
T-CTD	079	M900	05/11/10	22:22	6° 0.11' N	20° 0.02' W	1200	Tracer, Salinity
MSS	051	M901	06/11/10	04:42	6° 0.02' N	18° 58.70' W	506	
MSS	052	M901	06/11/10	05:24	5° 59.99' N	18° 59.32' W	497	
MSS	053	M901	06/11/10	06:05	5° 59.99' N	18° 59.82' W	513	
Bio-CTD	080	M902	06/11/10	06:13	6° 0.00' N	18° 59.91' W	400	O2, H2O2/Fe(II), Mn, CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
Plancton net	019	M903	06/11/10	06:45	6° 0.01' N	18° 59.96' W	100	
T-CTD bottom	081	M904	06/11/10	07:26	6° 0.00' N	19° 0.00' W	4723	Tracer, O2, H2O2/Fe(II), Mn, CDOM, Nutrients, Salinity
T-CTD	082	M905	06/11/10	20:20	5° 0.10' N	19° 59.92' W	1200	Tracer, Nutrients, DOM/POC, DNA, Salinity
T-CTD	083	M906	07/11/10	02:51	5° 0.02' N	20° 59.82' W	1200	Tracer, Nutrients, Salinity
Bio-CTD	083	M907	07/11/10	09:01	4° 0.05' N	20° 59.89' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
Plancton net	019	M908	07/11/10	09:35	4° 0.06' N	20° 59.89' W	100	
T-CTD	085	M909	07/11/10	10:11	4° 0.09' N	20° 59.86' W	1200	Tracer, O2, Nutrients, Salinity
T-CTD	086	M910	07/11/10	16:32	3° 0.05' N	21° 0.02' W	1200	Tracer, O2, H2O2/Fe(II), CDOM, Nutrients, DNA, POC, Salinity
MSS	054	M911	08/11/10	05:03	1° 57.36' N	23° 1.44' W	554	
MSS	055	M911	08/11/10	05:49	1° 57.68' N	23° 0.83' W	463	
MSS	056	M911	08/11/10	06:40	1° 57.95' N	23° 0.11' W	498	
GO-FLO	015	M912	08/11/10	06:46	1° 57.94' N	23° 0.06' W	70	Nutrients, Trace Metals (10, 30, 50)
Plancton net	020	M913	08/11/10	07:11	1° 57.98' N	23° 0.08' W	100	
Bio-CTD	087	M914	08/11/10	07:22	1° 57.96' N	23° 0.07' W	400	O2, H2O2/Fe(II), Mn, CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
GO-FLO	016	M915	08/11/10	08:06	1° 57.70' N	22° 59.79' W	310	Nutrients, Trace Metals (10, 110, 210)
T-CTD	088	M916	08/11/10	08:57	1° 57.70' N	22° 59.86' W	1200	Tracer, H2O2/Fe(II), Mn, CDOM, Nutrients, Salinity
T-CTD	089	M917	08/11/10	15:24	2° 59.99' N	23° 0.04' W	1200	Tracer, O2, H2O2/Fe(II), Nutrients, DNA, Salinity
T-CTD	090	M918	08/11/10	23:42	4° 0.09' N	23° 59.93' W	1200	Tracer, Salinity
MSS	057	M919	09/11/10	00:44	4° 0.28' N	23° 59.77' W	390	
MSS	058	M919	09/11/10	01:14	4° 0.66' N	23° 59.39' W	400	
MSS	059	M919	09/11/10	01:41	4° 0.82' N	23° 58.91' W	316	
Bio-CTD	091	M920	09/11/10	07:21	4° 3.01' N	22° 58.00' W	400	O2, H2O2/Fe(II), Mn, CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
Plancton net	021	M921	09/11/10	07:50	4° 3.01' N	22° 57.99' W	100	
T-CTD	092	M922	09/11/10	08:32	4° 3.03' N	22° 57.99' W	1200	Tracer, O2, H2O2/Fe(II), Mn, CDOM, Nutrients, Salinity
MSS	060	M923	09/11/10	09:50	4° 3.12' N	22° 57.94' W	497	
MSS	061	M923	09/11/10	10:28	4° 3.51' N	22° 57.84' W	490	
MSS	062	M923	09/11/10	10:56	4° 3.78' N	22° 57.77' W	516	
T-CTD	093	M924	09/11/10	18:12	5° 3.96' N	22° 59.92' W	1200	Tracer, O2, Nutrients, POM, DNA, Salinity
MSS	060	M925	09/11/10	19:17	5° 3.94' N	22° 59.70' W	428	
MSS	061	M925	09/11/10	19:44	5° 3.79' N	22° 59.81' W	483	
MSS	062	M925	09/11/10	20:13	5° 3.61' N	22° 59.93' W	485	
T-CTD	094	M926	10/11/10	01:44	6° 0.06' N	23° 0.01' W	1200	Tracer, Nutrients
MSS	063	M927	10/11/10	02:45	6° 0.00' N	22° 59.99' W	490	
MSS	064	M927	10/11/10	03:11	5° 59.79' N	23° 0.09' W	480	
MSS	065	M927	10/11/10	03:36	5° 59.59' N	23° 0.15' W	470	
Bio-CTD	095	M928	10/11/10	09:16	6° 59.96' N	23° 0.10' W	400	O2, H2O2/Fe(II), Mn, CDOM, Nutrients, DOM, Chl-a, POM, DNA, N2-fixation
Plancton net	022	M929	10/11/10	09:49	7° 0.02' N	23° 0.03' W	100	
T-CTD	096	M930	10/11/10	10:22	7° 0.18' N	23° 0.06' W	1200	Tracer, O2, H2O2/Fe(II), Mn, CDOM, Nutrients, Salinity
T-CTD	097	M931	10/11/10	16:52	8° 2.94' N	23° 0.05' W	1200	Tracer, O2, Nutrients, POM, DNA, Salinity, H2O2/Fe(II)

	P#	Stat.	Date	Time	Latitude	Longitude	max. p [db]	Comment
T-CTD	098	M932	10/11/10	22:42	9° 0.00' N	22° 59.96' W	1200	Tracer, Nutrients
MSS	066	M933	10/11/10	23:47	9° 0.03' N	22° 59.99' W		
MSS	067	M933	11/11/10	00:20	9° 0.33' N	23° 0.13' W	480	
MSS	068	M933	11/11/10	00:46	9° 0.13' N	22° 59.94' W	500	
MSS	069	M933	11/11/10	01:11	8° 59.89' N	22° 59.90' W	480	
Bio-CTD	099	M934	11/11/10	09:33	10° 29.99' N	23° 0.03' W	400	O2, H2O2/Fe(II), CDOM, Nutrients, DOM, Chl-a, POM, DNA
Plancton net	023	M935	11/11/10	10:06	10° 30.03' N	23° 0.09' W		
T-CTD	100	M936	11/11/10	10:38	10° 30.02' N	23° 0.02' W	1200	Tracer, Nutrients
T-CTD	101	M937	11/11/10	17:58	11° 30.04' N	23° 0.05' W	1200	Tracer, Nutrients
T-CTD	102	M938	12/11/10	04:02	12° 59.98' N	22° 59.86' W	1200	Tracer
T-CTD	103	M939	12/11/10	10:33	13° 59.88' N	23° 0.02' W	1200	no sample

8 Data and Sample Storage and Availability

The data were collected within the Kiel Sonderforschungsbereich (SFB) 754. In Kiel a joint Datamanagement-Team is active, which stores the data from the Kiel SFB-574, the Kiel SFB 754 and the Kiel Excellenzcluster in a webbased multi-user-system. In a first phase the data are only available to the user groups. After a three year proprietary time these data will be made public by distributing them to national and international data archives through the GEOMAR data management team, i.e. the data will be submitted to PANGEA no later than November 13 2013. When the data sets will be archived in the PANGAEA Open Access library digital object identifiers (DOIs) will be assigned.
All meta-data are available here https://portal.geomar.de/metadata/leg/show/307306 . And a kml (Google Maps) link is here https://portal.geomar.de/metadata/leg/kmlexport/307306 .

9 Acknowledgements

We like to thank captain Walter Baschek, his officers and crew of RV METEOR for their support of our measurement program and for creating a very friendly and professional work atmosphere on board. The ship time of METEOR was provided by the German Science Foundation (DFG) within the core program METEOR/MERIAN. Financial support for the different projects carried out during the cruise was mostly provided though the collaborative research program SFB 754 (Climate – Biogeochemical interactions in the tropical Oceans) supported by the German Science Foundation (DFG). We also benefited from the participation of P. Silva from the INDP (Cape Verde), J. Ly (Senegal) and S. Diallo CNSHB (Guinea) who helped with the sampling. We gratefully acknowledge all this support.

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